INSTRUCTION MANUAL

REGATRAN SEMICONDUCTOR POWER SUPPLY

MODEL PVC 36-30M

SERIAL No. 5C10537

MP MASTER
MA27877

ELECTRONIC
MEASUREMENTS
COMPANY OF RED BANK
EATONTOWN · NEW JERSEY

TELEPHONE: (201) LIberty 2-0300 TWX: (201) 542-2273 CABLE: ELMEASCO

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2. On receipt of shipping instructions, forward the appartus to us, prepaid, and we will make repairs and adjustments immediately at the factory.

3. If the fault has been caused by misuse, or abnormal conditions of operation, as disclosed by our examination, repairs will be billed at cost. In this case, an estimate of the cost will be submitted before work is started.

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Code S763

INSTRUCTION MANUAL

REGATRAN® PVC *POWER SUPPLY*

Model PVC36-30m

Serial No. _____

ELECTRONIC MEASUREMENTS

EATONTOWN NEW JERSEY

TELEPHONE: (201) 542-0300 TWX: (201) 542-2273 CABLE: ELMEASCO

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Eatontown, New Jersey

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ADDENDA TO PVC INSTRUCTION MANUAL
PVC SERIES .. SPECIFICATION TABLE

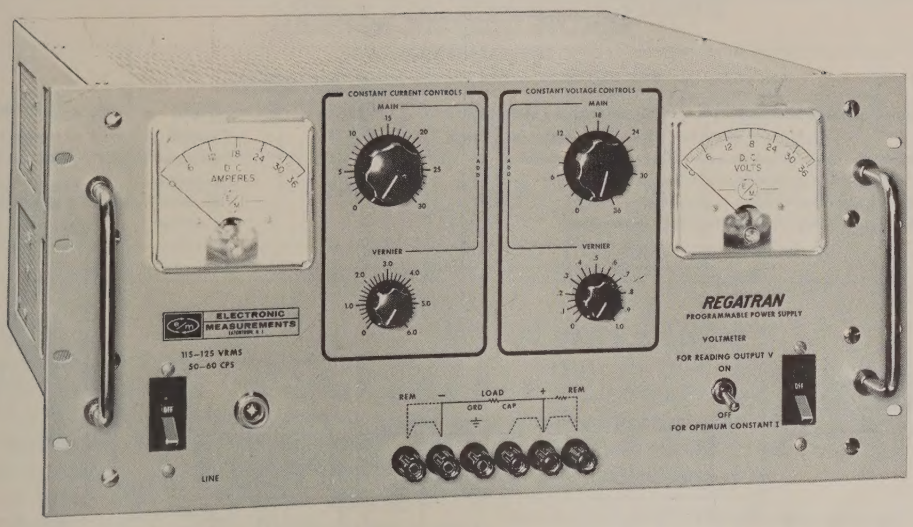
DC OUTPUT		RIPPLE		TRANSIENT RESP. Output Recovers		AC *	WATTS [2]	DIMENSIONS Depth Meas. Behind Panel			WT. IN	MODEL NO. with meters
		Eo	Io	TO	IN							
Volts	Amps	MV	MA	MV	uSEC	INPUT	INPUT	H	W	D	LBS.	ACC. F.S.
0-20	0-30	0.5	4	5	5	A or B	924	7	19	15-3/4	75	PVC20-30M
0-36	0-15	0.5	2	50	100	A or B	864	7	19	15-3/4	75	PVC36-15M
0-36	0-30	0.5	4	50	100	A or B	1722	8-3/4	19	18-3/4	113	PVC36-30M
0-36	0-60	1	12 [4]	5	5	B only	3550	8-3/4	19	20	148	PVC36-60M
0-36	0-100	1	12 [4]	5	5	B only	5700	8-3/4	19	15-3/4	153	PVC36-100M
0-60	0-7.5	0.5	2	100	100	A or B	794	7	19	15-3/4	75	PVC60-7.5M
0-60	0-15	0.5	4	100	100	A or B	1540	8-3/4	19	18-3/4	113	PVC60-15M
0-60	0-30	1	12 [4]	5	5	B only	2900	8-3/4	19	20	153	PVC60-30M

* AC Input
50-60 CPS. 1 ϕ
A = 105-125V
B = 198-242V

[2] At max. input line voltage.

[4] Or 0.02%

[5] Not available at time of printing.



SECTION I
DESCRIPTION

1-1. GENERAL. This Series PVC Regatran® is a high performance dc power supply with an exceptional degree of versatility. Standard features include: two independent regulator channels, one for constant-voltage, one for constant-current, with sharp automatic crossover for control or limiting in either mode; SCR input control; extremely close regulation; calibrated constant-voltage and constant-current controls; full range programming* and Mhogramming(TM); remote sensing; long line operation; external slaved operation including parallel and series modes; and rear apron controls for amplifier nulling and calibration. Chopper stabilization is available as an optional feature for the voltage channel.

Complete solid state design is used throughout. Resulting advantages include instant start-up, compact size, and high efficiency and reliability. In addition, the power supply incorporates all silicon semiconductor components which result in greater reliability and temperature tolerance than is generally realized in a germanium system. In spite of its unusual features, performance, and versatility, the Series PVC Regatran is one of the most compact highly regulated dc sources available today. Additional detailed performance data is given in the Table of Specifications.

*Patents issued and pending.

1-2. PROGRAMMING. The output of this power supply can be programmed over the full constant-voltage or constant-current range with a resistor located externally or remotely. Output then depends directly on the value of the control resistance in a fixed ratio, with regulation and stability maintained within specified ratings. The programming constants for this power supply are given in the Table of Specifications.

1-3. MHOGRAMMING.(TM) The output voltage of this power supply can also be Mhogrammed, or remotely controlled by conductance programming with a resistor connected externally. Output is then inversely proportional to the value of the resistor and varies proportionally with conductance. Thus, an open in the remote control circuit, or zero conductance, develops zero volts, and higher conductances develop higher voltages up to maximum available voltage. This property offers an important fail-safe feature in the fact that an open, the more likely event, results in a drop to zero voltage. The Mhogramming constant for this power supply is given in the Table of Specifications.

1-4. REMOTE SENSING. In local, programmed, or Mhogrammed operation, this power supply permits connection of the load by the remote sensing method which results in voltage regulation directly at the load.

REMOTE CONTROL METHODS

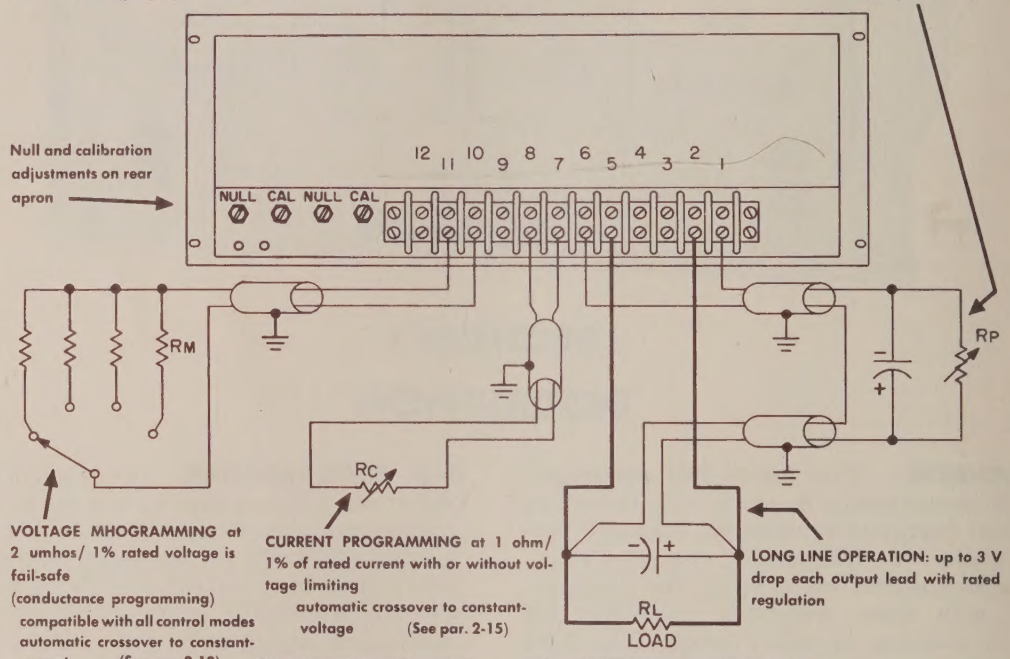
and outstanding features of

PVC All-Silicon Constant Voltage/Current Power Supplies

- Master-slave operation: parallel for higher-than-single-unit current series for higher-than-single-unit voltage
- Mode of operation can be selected or changed without removal of covers or equipment from rack mounting
- Among the most compact in the industry today
- Removable (plug-in) series heat sink assemblies

VOLTAGE PROGRAMMING at 1000 ohms/V for local control w/ local or remote sensing

- remote control w/ local or remote sensing
- automatic crossover to constant-current (See para. 2-11)


Null and calibration adjustments on rear apron
12 11 10 9 8 7 6 5 4 3 2 1
NULL CAL NULL CAL
RM
RC
RP
RL
LOAD
VOLTAGE MHOGRAMMING at 2 umhos/ 1% rated voltage is fail-safe
(conductance programming)
compatible with all control modes
automatic crossover to constant-current (See par. 2-13)
CURRENT PROGRAMMING at 1 ohm/ 1% of rated current with or without voltage limiting
automatic crossover to constant-voltage (See par. 2-15)
LONG LINE OPERATION: up to 3 V drop each output lead with rated regulation

automatic voltage / current crossover

	Voltage Regulation*	Current Regulation*
LINE	0.01% or 2mv	0.05% or 8ma
LOAD	0.01% or 2mv	0.05% or 8ma

*Without switching or reconnection.

1-5. LONG LINE OPERATION. The advanced regulator systems employed in this power supply permit operation with a remote load, remote sensing, programming, or Mhogramming with as much as a 3-volt IR drop in each power line. Thus, the programming or Mhogramming control resistance, the power supply, and the load can all be spaced widely apart, if necessary. For example, this facility is extremely useful in missile launching sites where, typically, the load is in the bird, the power supply in the gantry, and the controls in the blockhouse.

1-6. SERIES, PARALLEL, OR SLAVED OPERATION. Two Series PVC power supplies can be operated in series or parallel. In series, each supply can be adjusted separately so that the total output is the sum of two voltages; or one can be slaved to a master so that the master controls both supplies. In parallel, one supply can be slaved to the other so that the output currents are added.

1-7. STANDARD VERSIONS. This Regatran power supply is available in any of several standard versions: metered or unmetered; with or without panel controls. This instruction manual is essentially applicable to all of these standard versions.

TABLE OF SPECIFICATIONS

Model	DC Output		Dimensions in Inches			Approx. Weight In Lbs.
	Volts	Amps	Panel H	Panel W	Depth Behind Panel	
PVC36-30	0-36	0-30	8-3/4	19	18-3/4	113
PVC60-15	0-60	0-15	8-3/4	19	18-3/4	113

REGULATION

Constant-Voltage: Line, 0.01% or 2 millivolts from 105 to 125 volts (198 to 242 volts). Load, 0.01% or 2 millivolts from no load to full or full to no load.

Constant-Current: Line, 0.05% or 8 milliamperes from 105 to 125 volts (198 to 242 volts). Load, 0.05% or 8 milliamperes from no load to full or full to no load.

RIPPLE

Constant-Voltage: 0.5 millivolt rms, positive or negative ground.

Constant-Current: 4 milliamperes rms, positive or negative ground.

STABILITY

0.05% +3 millivolts for 8 hours after warmup, under fixed line, load, and temperature conditions.

PROGRAMMING CONSTANT

Voltage Output: 1000 ohms-per-volt.

Current Output: 1 ohm per 1% of rated current.

MHOGRAMMING CONSTANT

200 micromhos for 100% of rated voltage (2 micromhos per 1%).

TRANSIENT RESPONSE

For step change from no load to full, or full to no load, output recovers to within 50 millivolts of initial value within 100 microseconds for Model PVC36-30; and to within 100 millivolts of initial value within 100 microseconds for Model PVC60-15.

OUTPUT IMPEDANCE

0.002 ohm at 1KC

0.2 ohm at 100KC

AMBIENT TEMPERATURE RANGE

Operating: -25°C to 60°C.

Non-Operating: -40°C to +75°C.

REMOTE SENSING

3-volt IR drop in each load lead can be compensated by means of remote sensing connection of load, retaining rated line regulation, and permitting load regulation of 0.05% or 10 millivolts.

OUTPUT POLARITY

Positive or negative output with respect to ground, or floating output.

CIRCUIT PROTECTION

Constant-current protects load and power supply. Fuses or circuit breakers, depending on current rating, protect power supply ac input and regulated dc output lines.

CONTROLS

All front panel controls are wirewound type. Main voltage and current controls cover 0 to rated output. Voltage vernier range is 0 to 1 volt. Current vernier range is 0 to 20% (0 to 10-1/2% for some models) of rated current. Panel calibrations approximate. Null and calibration screwdriver adjust controls on rear apron.

METERS

Panel mounted voltmeter and ammeter are optional. Meter accuracy is ±2% full scale.

TERMINATIONS

Rear: Barrier type terminal strip.

Front: Universal insulated binding posts.

Line Cord: 3-conductor type.

AC INPUT

105 to 125 volts rms or 198 to 242 volts rms, 50 to 65 cps, single-phase power. The 115-volt version is normally supplied unless 220-volt input is specified.

FINISH

Smooth gray semi-gloss enamel Class 2 per MIL-E-15090. Panel markings are silk-screened in red, green, and black.

MOUNTING

Fits standard 19-inch rack and equipped with rubber feet for table use.

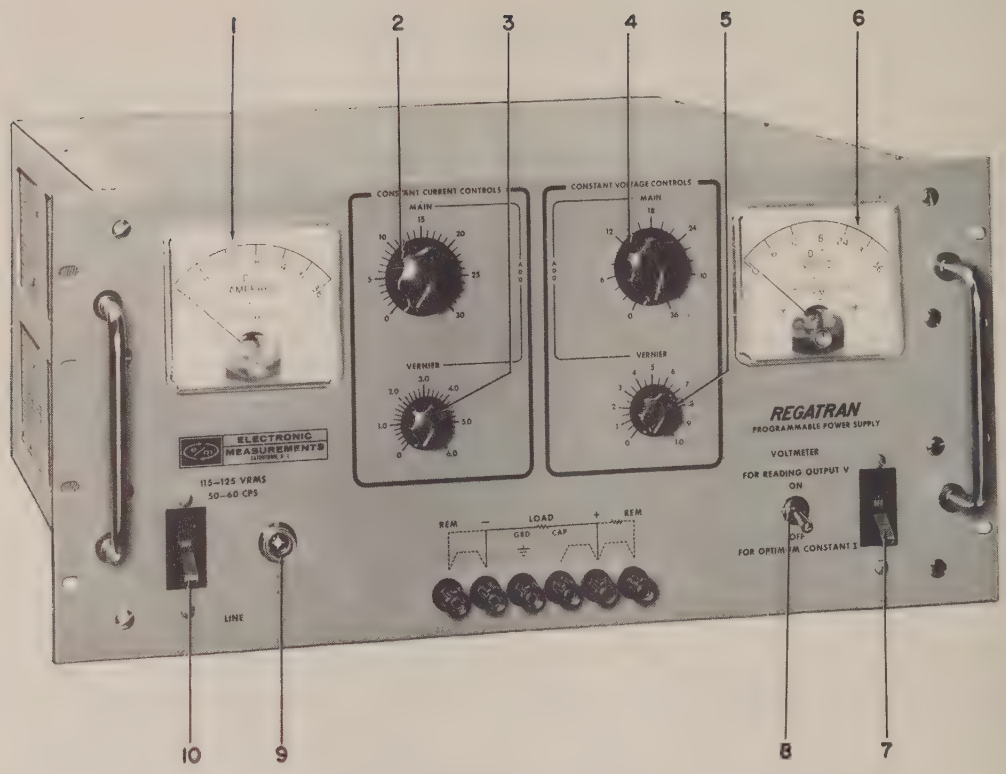


Figure 2-1. Series PVC Regatran power supply, typical front panel (see figure 2-2)

SECTION II

OPERATION

2-1. PREPARATION. Immediately upon unpacking the power supply, perform a visual inspection for internal or external damage incurred in shipment. If damage is discovered, follow the Claim for Damage in Shipment instructions on the Warranty, printed on the front inside cover of this instruction manual. Before placing the power supply in operation for the first time, make certain that all shipping blocks have been removed from inside the unit, and check to see that all transistors are securely seated in their sockets.

2-2. INSTALLATION. This power supply may be placed on a table or mounted in a standard 19-inch rack with sufficient depth to accommodate the chassis. In rack mounting, make certain that adjacent equipment does not completely block the power supply ventilation openings. The covers may be removed to increase ventilation when required by ambient temperature conditions, except for those units where covers form part of an air-duct system.

2-3. CONTROLS AND INDICATORS. The following controls and indicators are located on the front panel of the power supply (see figure 2-1), unless otherwise specified. Numbers in parentheses after panel designations are index numbers by which the controls and indicators are identified in figures 2-1 and 2-2.

2-4. CIRCUIT PROTECTION. (See figure 2-1.) The ac input circuit is protected by one of two methods; LINE fuse F1 (on panel for switch operated units only), or LINE (10) magnetic circuit breaker CB1. The dc output circuit is also protected by one of two methods; DC fuse F2 (on panel for switch operated units only), or DC (7) magnetic circuit breaker CB2. In addition, the power supply and load are further protected by automatic crossover to constant-current.

2-5. INITIAL CONTROL SETTINGS. Before plugging the line cord into the ac power outlet, check that:

Control or Indicator	Function
(1) D.C. AMPERES meter (metered units only)	Monitors output current.
CONSTANT CURRENT CONTROLS	(2) MAIN: Adjusts output current. Calibrated to dial markings on panel.
	(3) VERNIER: Provides fine adjustment of output current. MAIN and VERNIER current control settings are additive.
CONSTANT VOLTAGE CONTROLS	(4) MAIN: Adjusts output voltage. Calibrated to dial markings on panel.
	(5) VERNIER: Provides fine adjustment of output voltage. MAIN and VERNIER voltage control settings are additive.
(6) D.C. VOLTS meter (metered units only)	Monitors output voltage.
(7) D.C. magnetic circuit breaker	Magnetic circuit breaker trips on current overload. Has manual reset.
(8) VOLTMETER switch	Disconnects D.C. VOLTS meter to prevent 1 milliampere current of meter from affecting regulation in constant-current mode of operation.
D.C. indicator lamp (switch operated units only)	Indicates application of dc output voltage to load.
(9) LINE indicator lamp	Indicates application of ac power input to unit.
(10) LINE magnetic circuit breaker or switch	Controls application of ac power input to unit. Magnetic circuit breaker trips on ac overload and has manual toggle reset.
VOLTAGE screwdriver adjust controls (on rear)	NULL: To zero balanced input detector of voltage control system. CAL: Calibrates output voltage to panel markings, or to exact programming constant.
CURRENT screwdriver adjust controls (on rear)	NULL: To zero balanced input detector of current control system. CAL: Calibrates output current to panel markings, or to exact programming constant.

Figure 2-2. Controls and indicators.

a. LINE switch or magnetic circuit breaker is off.

b. DC switch is off or magnetic circuit breaker is on.

c. CONSTANT VOLTAGE CONTROLS and CONSTANT CURRENT CONTROLS are at minimum (fully counterclockwise).

2-6. LINE AND LOAD CONNECTIONS. Make the following line and load connections:

a. Plug the line cord into the ac power outlet.

b. Connect load between the + and - output terminals. Make connections with barrier strip to establish desired mode of operation, or use the fanning strip supplied for local operation.

It should be noted that the regulation of this unit is measured at the output terminals. To maintain a desired regulation at the load, the load wires must be heavy enough to prevent substantial voltage drops between the output terminals and the load. Refer to paragraph 2-12 for remote connections to maintain regulation directly at the load.

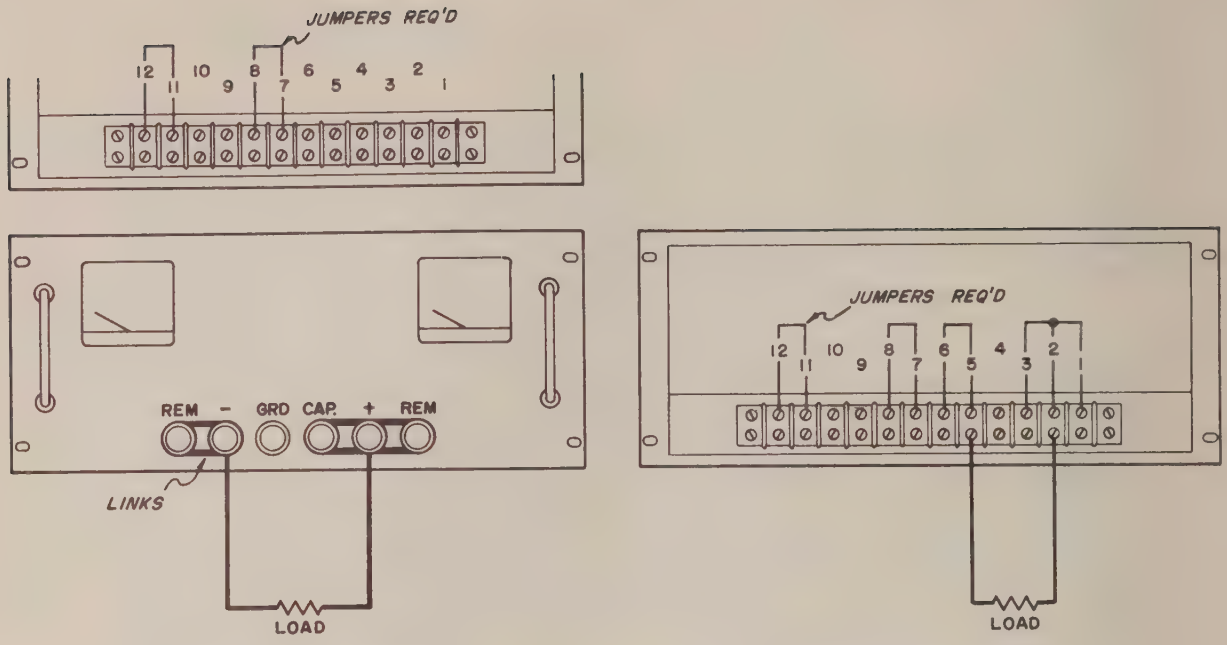
2-7. LOCAL OPERATION, FRONT TERMINALS. For this mode of operation, make the connections shown in figure 2-3A, and perform the following steps:

a. Set the LINE switch or circuit breaker to the on position. The LINE indicator lamp should light.

b. For constant-voltage output, set the CONSTANT CURRENT CONTROLS above the maximum expected current value (10 percent of rating will usually suffice), and advance the CONSTANT VOLTAGE CONTROLS to provide the required output voltage. For an output of one volt or less, turn the MAIN voltage control to zero and use only the VERNIER to realize greater stability and resolution.

c. For constant-current output, set the CONSTANT VOLTAGE CONTROLS to at least one volt above the maximum expected voltage value, and adjust the CONSTANT CURRENT CONTROLS to provide the required output current. For current control settings below 20 percent of the rated output current of the power supply, it is recommended that the MAIN current control be set at zero and that only the VERNIER be used to set the desired current.

d. Set the DC switch (where provided) to the on position. The DC indicator lamp (where provided) should light. Output voltage is now applied to the load.



A. USING FRONT TERMINALS

B. USING REAR TERMINALS

Figure 2-3. Local control, local sensing .

It should be noted that constant-voltage output crossing over automatically to constant current output (or vice-versa) is inherent in the operation of this power supply. Transition occurs at a load resistance of

$$R_L = \frac{E_o \text{ (voltage output setting)}}{I_c \text{ (current control setting)}}$$

Crossover occurs automatically as the load shifts in resistance through this transition value; an upward shift developing constant-voltage, a downward shift drawing constant-current. Thus, mode of regulation depends on control settings relative to load resistance.

2-8. LOCAL OPERATION, REAR TERMINALS. For this mode of operation, make the connections shown in figure 2-3B, and perform steps a through d, paragraph 2-7.

Note

It is not possible to obtain sensing at the front and rear terminals simultaneously. For front terminal sensing, use figure 2-3A. For rear terminal sensing, use figure 2-3B.

2-9. CASE GROUND. To change polarity of case ground, loosen the dc output and GND connections, swing the ground link to the desired output terminal, and retighten the connections. For floating output do not connect the link to either terminal.

2-10. REMOTE SENSING, LOCAL CONTROL. The connections shown in figure 2-4 permit remote sensing at the load to eliminate the effect of voltage drops in the output leads, thus providing regulation directly at the load. For this type of operation the voltage drop in each power lead should not exceed 3 volts. It is desirable to keep this drop as low as possible because it subtracts from the available output voltage. The positive and negative sense lines may have up to two ohms resistance. Note that internal output capacitor C9 is disconnected and an equivalent value capacitor is connected at the load.

2-11. PROGRAMMING OF CONSTANT-VOLTAGE. The output voltage of this power supply can be programmed, or remotely controlled, with resistor R_C connected as shown in figure 2-5 or 2-6. The remote control lines must be of equal length and must run together as shown. Note the addition of a 4.7 uf capacitor across resistor R_C.

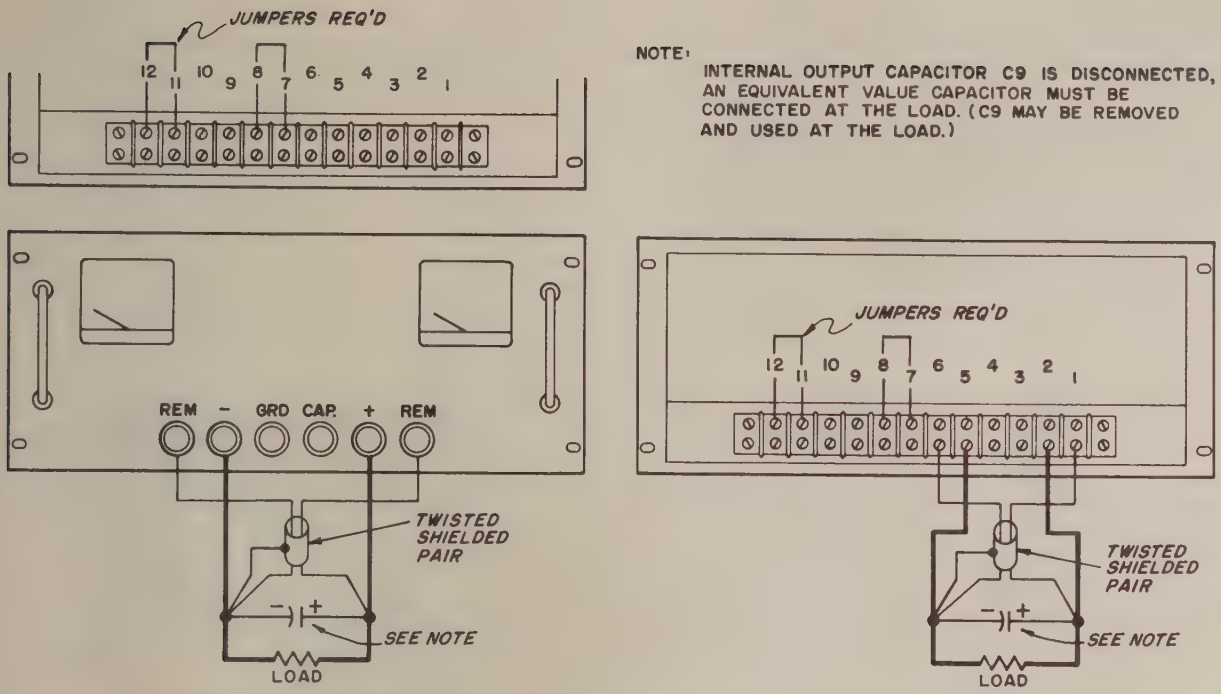

JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
REM - GRD CAP. + REM
TWISTED SHIELDED PAIR
SEE NOTE
LOAD
A. USING FRONT TERMINALS
NOTE:
INTERNAL OUTPUT CAPACITOR C9 IS DISCONNECTED, AN EQUIVALENT VALUE CAPACITOR MUST BE CONNECTED AT THE LOAD. (C9 MAY BE REMOVED AND USED AT THE LOAD.)
JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
TWISTED SHIELDED PAIR
SEE NOTE
LOAD
B. USING REAR TERMINALS

Figure 2-4. Remote sensing, local control.

The programming constant, or ratio of external control resistor R_C to output voltage, is given in the Table of Specifications. This constant is defined in ohms of control resistance required for each volt of output. Thus, 10,000 ohms of control resistance develops 10 volts in a unit with a 1000 ohms-per-volt constant. Similarly, 750 ohms develops 0.75 volt, etc.

For programming of constant-voltage, proceed as follows:

a. Turn the power supply off. Set the CONSTANT VOLTAGE CONTROLS to zero, and set the CONSTANT CURRENT CONTROLS above the maximum expected current value (10 percent above rating will usually suffice).

b. Connect the load and external control resistor as shown in figure 2-5 for local sensing, or as shown in figure 2-6 for remote sensing with regulation directly at the load. Note that a 4.7 uf capacitor must be connected across control resistor R_C. For remote load sensing (figure 2-5), output capacitor C9 must be disconnected and an equivalent value capacitor must be connected directly across the load.

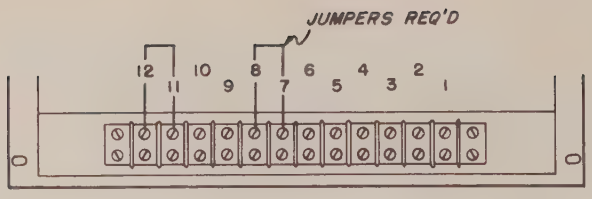
Note

An open in the remote control circuit is effectively a high programming resistance and, accordingly, will cause an uncontrolled voltage rise to the maximum output of the power supply. For this reason, switching of programming resistors should be on a make-before-break basis.

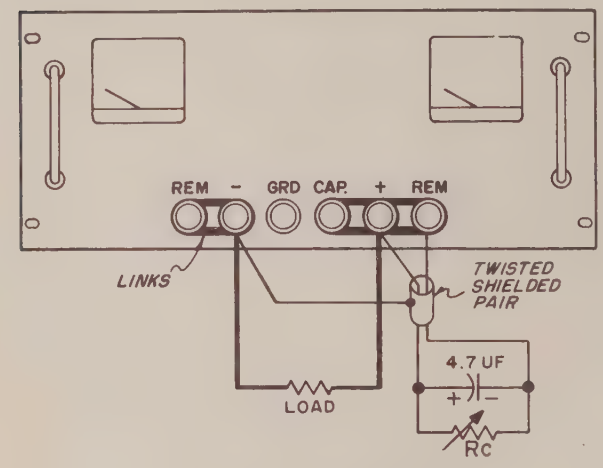
c. Set the LINE switch or magnetic circuit breaker to the on (up) position.

d. Set the DC switch (where provided) to the on position. Programmed voltage is now applied to the load.

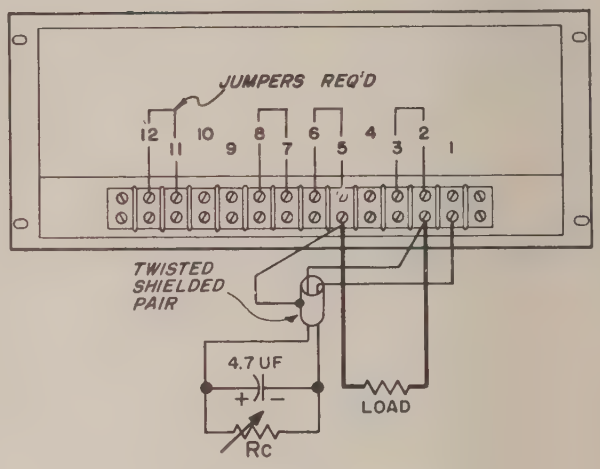
In programmed operation, the external control resistor is placed in series with the CONSTANT VOLTAGE CONTROLS, which are normally set to zero as in step a, above. However, where necessary or convenient, programmed (remote) operation may be combined with the use of the internal (local) controls. Output voltage will then be determined by the total value of the external control resistor and the resistance to which the CONSTANT VOLTAGE CONTROLS are adjusted. It should be understood that for long term or permanent programmed operation, it is



NOTES:
1. SHORT OUT CONSTANT VOLTAGE MAIN AND VERNIER CONTROLS OR SET TO ZERO.
2. R_C = REMOTE CONTROL RESISTOR 1000 Ω PER VOLT.

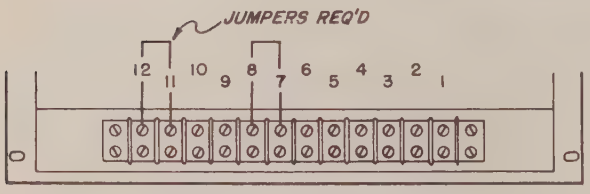


A. USING FRONT TERMINALS

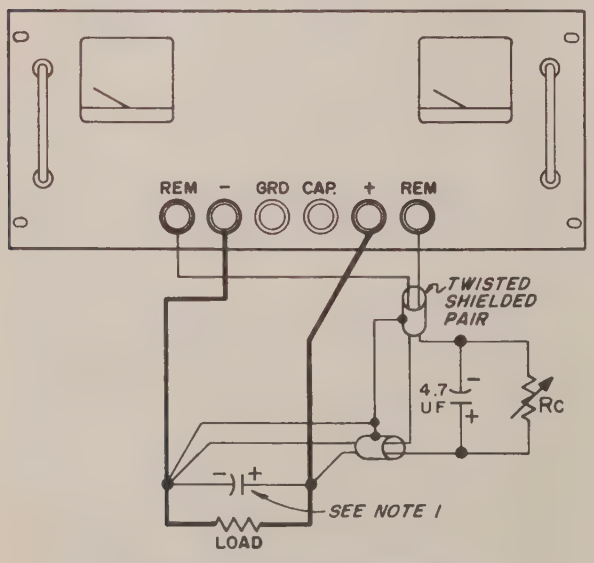


B. USING REAR TERMINALS

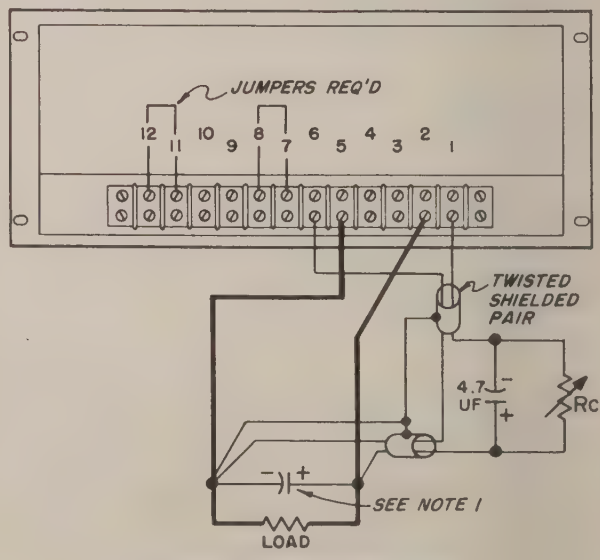
Figure 2-5. Programming of constant-voltage, local sensing.



NOTES:
1. INTERNAL OUTPUT CAPACITOR C9 IS DISCONNECTED, AN EQUIVALENT VALUE CAPACITOR MUST BE CONNECTED AT THE LOAD. (C9 MAY BE REMOVED AND USED AT THE LOAD.)
2. SHORT OUT CONSTANT VOLTAGE MAIN AND VERNIER CONTROLS OR SET TO ZERO.
3. R_C = REMOTE CONTROL RESISTOR 1000 Ω PER VOLT.



A. USING FRONT TERMINALS



B. USING REAR TERMINALS

Figure 2-6. Programming of constant-voltage, remote sensing.

advisable to short out the internal controls in order to eliminate possible disturbance of programmed voltage from accidental rotation or vibration, and to provide, in general, greater stability.

Regatran power supplies are normally calibrated at the factory for close agreement between actual output and front panel dial indications. Thus, in programmed operation the ratio between voltage and the external control resistance may be somewhat more or less than the nominal ohms-per-volt programming constant specified for the power supply, depending upon the tolerance variations of the internal panel control potentiometers from their rated values. Therefore, if precisely the nominal ohms-per-volt constant is required, this power supply should be recalibrated by using a precision decade or resistor for the external control resistance. The calibration procedure is given in paragraph 4-5.

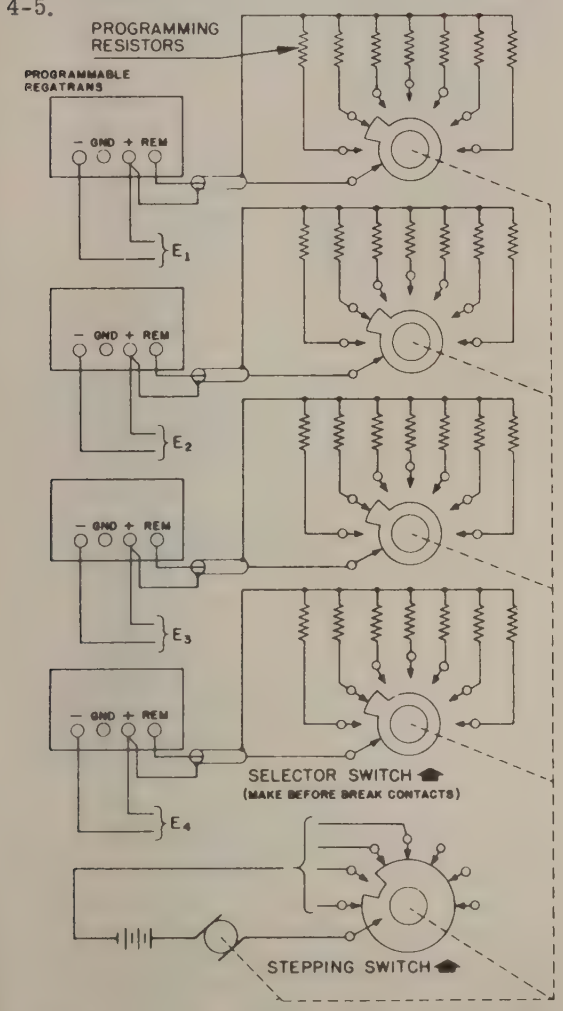


Figure 2-7. Programming with stepper switch.

2-12. MULTI - VOLTAGE PROGRAMMING METHODS. Although the above programming instructions are illustrated with a single fixed resistor as the remote control, it is evident that variable resistors, driven potentiometers, or fixed resistors wired to stepping switches can be employed to deliver voltages in a wide variety of time/amplitude patterns. The time required for switching from one programmed voltage to another varies from the seconds to the milliseconds range, depending upon conditions. Data on modification for changing switching speed is available upon request.

It is also evident that programming can be manually or automatically actuated. Figure 2-7 illustrates a four-level rotary switch, each level of which controls one Regatran supply. As shown, the entire battery can be stepped through a sequence of four programmed outputs upon command. In an extensive system, a central board may contain the switches or rheostats for the programming of several Regatran power supplies in different locations. In such a system it is practical to calibrate the control elements directly to dial markings, remembering that the accuracy of calibration depends upon the accuracy of the resistance and/or the dial markings.

2-13. MHOGRAMMING OF CONSTANT-VOLTAGE. The output of this power supply can be Mhogrammed, or remotely controlled by conductance programming, with resistor R_m connected externally as shown in figure 2-8 or 2-9. Output voltage is then inversely proportional to the resistance of R_m and varies proportionally with conductance.

The Mhogramming constant for this power supply is 200 micromhos for 100 percent of maximum voltage. Conductance can easily be calculated for other percentages of maximum voltage. The conductance required for any given voltage is

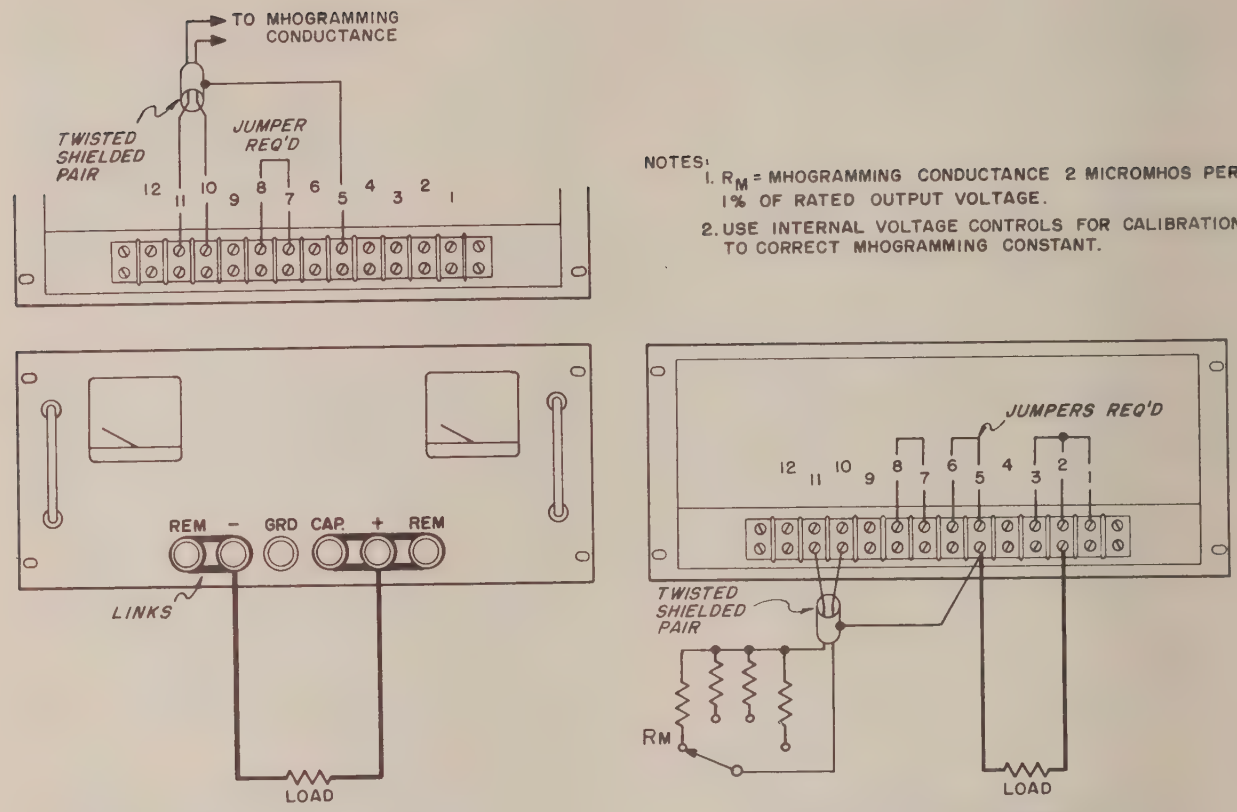
$$g_2 = \frac{Pgk}{100}$$

where P = percentage of full voltage desired, and gk = Mhogramming constant, as described above.

With conductance expressed in micromhos, the resistance of R_m is readily calculated from

$$R_m = \frac{10^6}{g_2}$$

Since voltage varies directly with conductance, the value of R_m indicates the fraction or per-



NOTES:
1. R_M = MHOGRAMMING CONDUCTANCE 2 MICROMHOS PER 1% OF RATED OUTPUT VOLTAGE.
2. USE INTERNAL VOLTAGE CONTROLS FOR CALIBRATION TO CORRECT MHOGRAMMING CONSTANT.

Figure 2-8. Mhogramming of constant-voltage, local sensing.

centage of the maximum voltage of the power supply which is actually developed, rather than a numerical value. Thus, if a conductance of 200 micromhos (an R_m of 5000 ohms) develops maximum output voltage, a conductance of 100 micromhos develops one-half the maximum voltage of the supply. 20 micromhos develops 10 percent of maximum voltage, and 2 micromhos (R_m of 500,000 ohms) develops 1 percent of maximum voltage.

To calibrate for Mhogrammed operation, proceed as follows:

a. Turn the power supply off. Set the panel controls for zero output voltage and current.

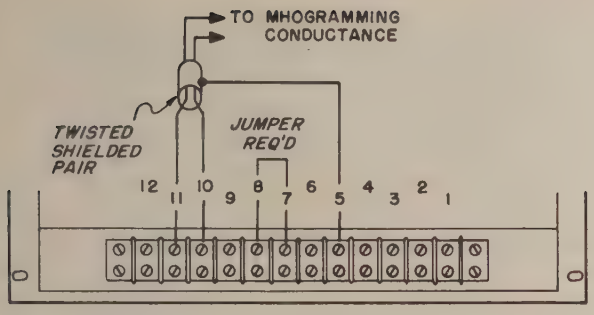
b. Make the connections shown in figure 2-8 for local sensing, or as shown in figure 2-9 for remote sensing with regulation directly at the load. A precision 5000-ohm resistor should be used for R_m.

c. Turn the power supply on. Adjust the CONSTANT VOLTAGE CONTROLS to obtain an output voltage of exactly the maximum rated voltage, and set the CONSTANT CURRENT CONTROLS for maximum output current. The CONSTANT VOLTAGE CONTROLS should be left at the aforementioned setting or a fixed resistor and trimmer resistor may be substituted for greater mechanical stability. Where substitution is made, the resistor used should be of a highly stable wire-wound type.

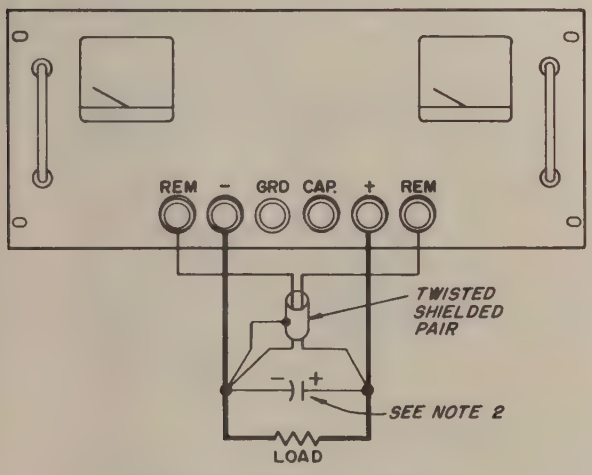
d. The power supply is now calibrated for the correct Mhogramming constant. The output voltage is now determined by the value of Mhogramming resistor R_m according to the Mhogramming constant.

Note

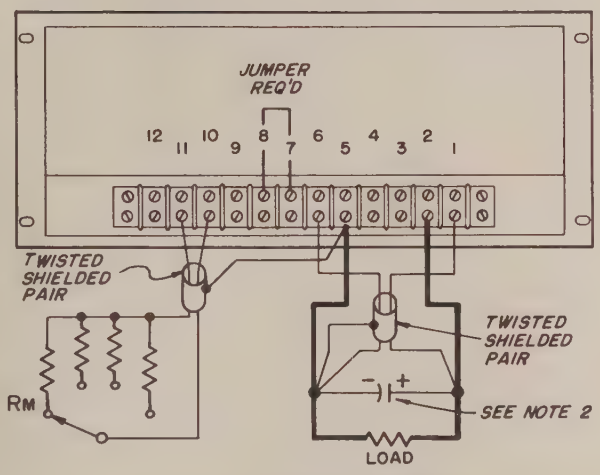
A short in the Mhogramming lines is analogous to an open in programming lines and, accordingly, will cause an uncontrolled voltage rise to the maximum output of the supply. Although repeated shorts are not advisable, no damage to the power supply will result.



NOTES:
1. R_M = MHOGRAMMING CONDUCTANCE 2 MICROMHOS PER 1% OF RATED OUTPUT VOLTAGE.
2. INTERNAL OUTPUT CAPACITOR C9 IS DISCONNECTED, AN EQUIVALENT VALUE CAPACITOR MUST BE CONNECTED AT THE LOAD. (C9 MAY BE REMOVED AND USED AT THE LOAD.)
3. USE INTERNAL VOLTAGE CONTROLS FOR CALIBRATION TO CORRECT MHOGRAMMING CONSTANT.



A. USING FRONT TERMINALS



B. USING REAR TERMINALS

Figure 2-9. Mhogramming of constant-voltage, remote sensing.

2-14. REMOTE CONTROL AND SENSING LINES. There are three main combinations to be considered. These are listed below together with the precautions that apply in each case.

a. Local Control, Remote Sensing. (See figure 2-4.) In this case, the plus and minus remote lines should be of equal length, twisted, and shielded.

b. Remote Control, Local Sensing. (See figures 2-5 and 2-8.) In this case, the control lines from the plus remote and plus power terminals should be of equal length, twisted, and shielded.

c. Remote Control, Remote Sensing. (See figures 2-6 and 2-9.) In this case, again, the remote lines should be of equal length, twisted, and shielded. If the control rheostats are physically located off to one side, the plus and minus remote lines should run to the rheostat and away from the rheostat so that both lines experience the same fields, thus providing cancellation of unwanted signals.

2-15. PROGRAMMING OF CONSTANT-CURRENT (LINEAR WITH RESISTANCE). The output current of this power supply can be programmed (remotely controlled) by means of an external resistor, R_C, of small wattage. A fixed resistor can be used to provide a fixed constant-current output, or a series of switch-selected resistors can be employed to provide discrete currents. In addition, non-linear potentiometers (rheostat connected) can be employed to provide various waveforms.

The programming constant, or ratio of external control resistance to output current, is given in the Table of Specifications. This constant is defined in ohms of control resistance required to develop a given percentage of the rated current output of the power supply. Thus, with a power supply utilizing 100 ohms for full rated current output, the value of the control resistor, R_C, for any desired current, I, is given by

$$R_C = \frac{I}{I \text{ max.}} \times 100$$

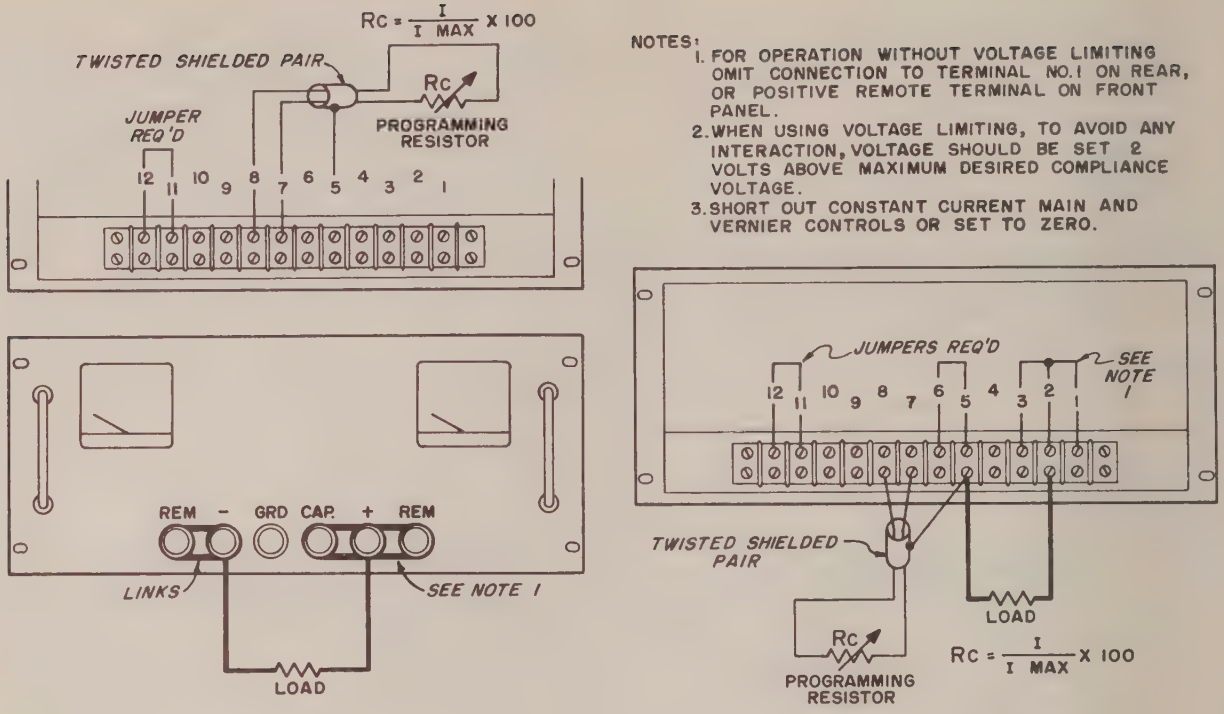

Rc = I / I MAX X 100
TWISTED SHIELDED PAIR
Rc
JUMPER REQ'D
PROGRAMMING RESISTOR
12 11 10 9 8 7 6 5 4 3 2 1
REM - GRD CAP. + REM
LINKS
SEE NOTE 1
LOAD
A. USING FRONT TERMINALS
NOTES:
1. FOR OPERATION WITHOUT VOLTAGE LIMITING OMIT CONNECTION TO TERMINAL NO.1 ON REAR, OR POSITIVE REMOTE TERMINAL ON FRONT PANEL.
2. WHEN USING VOLTAGE LIMITING, TO AVOID ANY INTERACTION, VOLTAGE SHOULD BE SET 2 VOLTS ABOVE MAXIMUM DESIRED COMPLIANCE VOLTAGE.
3. SHORT OUT CONSTANT CURRENT MAIN AND VERNIER CONTROLS OR SET TO ZERO.
JUMPERS REQ'D
SEE NOTE 1
12 11 10 9 8 7 6 5 4 3 2 1
TWISTED SHIELDED PAIR
LOAD
Rc
PROGRAMMING RESISTOR
Rc = I / I MAX X 100
B. USING REAR TERMINALS

Figure 2-10. Programming of constant-current (linear with resistance)

For programming of constant-current, proceed as follows:

a. Turn the power supply off. Set the CONSTANT VOLTAGE CONTROLS one volt above the maximum expected voltage value, and set the CONSTANT CURRENT CONTROLS to zero.

b. Connect the load and external control resistor as shown in figure 2-10.

Note

An open in the remote control circuit is effectively a high programming resistance and, accordingly, will cause an uncontrolled current rise to the maximum output of the power supply. For this reason, switching of programming resistors should be on a make-before-break basis.

c. Set the LINE switch or magnetic circuit breaker to the on (up) position.

d. Set the DC switch (where provided) to the on position. Programmed current is now flowing through the load.

e. After checking the voltage, set the VOLTMETER switch to the off position to prevent the 1 milliampere current of the panel voltmeter from affecting regulation.

f. If the exact programming constant specified for this power supply is required, perform the calibration procedure given in paragraph 4-10.

g. If it is desired to obtain constant-current output without the benefit of voltage limiting, remove the jumper between terminals 1 and 2 of the rear terminal strip.

2-16. PROGRAMMING OF CONSTANT-CURRENT (LINEAR WITH CONDUCTANCE). (See figure 2-11.) Normally the internal sample resistor, R14, together with the CONSTANT CURRENT CONTROLS determine the output current. The maximum reference voltage is 1 volt; therefore, the maximum output current is 1 volt divided by the resistance of R14. To use this method, set the CONSTANT CURRENT CONTROLS to maximum and return the load to terminal 7; then adjust the total current by inserting a resistor, R_S, between terminals 7 and 5. The value of this resistor for any current is given by the simple relationship:

NOTES:
1. FOR OPERATION WITHOUT VOLTAGE LIMITING OMIT CONNECTION TO TERMINAL NO. 1.
2. WHEN USING VOLTAGE LIMITING, TO AVOID ANY INTERACTION, VOLTAGE SHOULD BE SET 2 VOLTS ABOVE MAXIMUM DESIRED COMPLIANCE VOLTAGE.

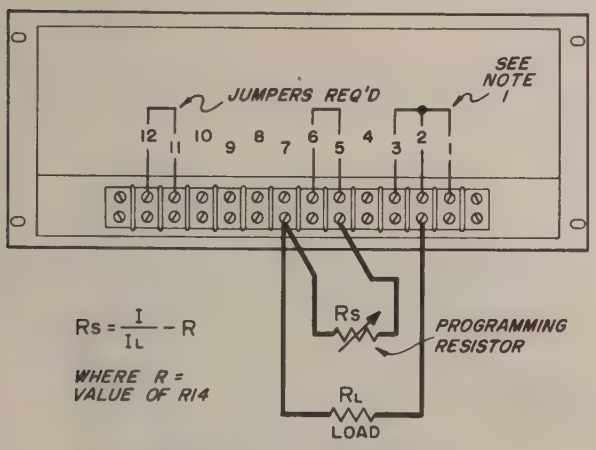


Figure 2-11. Programming of constant-current (linear with conductance).

$$R_S = \frac{1}{I_L} - R$$

where R is R14. In general, the programming constant is linear with conductance and is one mho per ampere, where the net conductance is given by

$$\frac{1}{R14} + \frac{1}{R_S}$$

It should be noted that the programming resistor carries the full load current, and lead resistance to this resistor may become a factor. The main characteristics of this method may be briefly described as follows:

a. The system provides maximum resolution at all current values; thus permitting a very large effective current ratio. Current ratios of several hundred to one are practical.

b. This method provides an exactly linear relationship between conductance and output current.

c. One disadvantage of this method is that the total load current must pass through the programming resistor, R_S.

d. Another disadvantage is that the error in the internal sample resistor system (R14 and wiring) appears as an error in the external programming constant. If the current must be preset to better than 10 percent, the exact resistance required must be determined by experiment.

2-17. CONSTANT-CURRENT BY EXTERNAL CONVERSION. Essentially, the main advantage in this case is that the sample voltage can be made of the value required to produce a given degree of regulation. In addition, variation of current by changing the sample resistor, rather than the sample voltage as normally done, can result in considerably higher resolution. To obtain constant-current output by the external conversion method, proceed as follows:

a. Select resistor R_S in figure 2-12, which will carry the load current and develop a sample voltage for the control system. To determine its value, select a sample voltage (usually from 1 to 5 volts). Although the voltage may be made as high as desired, it must be remembered that the sample voltage subtracts from the available output voltage. If E_S is the sample voltage and I_L is the desired load current, then

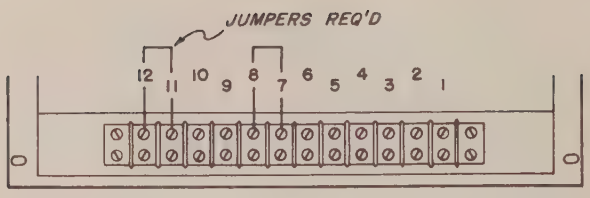
$$R_S = \frac{E_S}{I_L}$$

where R_S is in ohms and I_L is in amperes. The actual wattage will be $E_S \times I_L$.

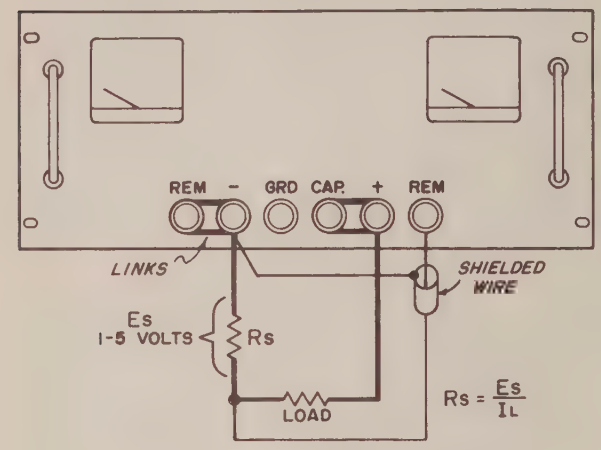
b. Make connections shown in figure 2-12.

c. If the resolution of the internal controls is considered adequate for the purpose, rotate the CONSTANT CURRENT CONTROLS fully clockwise and adjust output current by means of the CONSTANT VOLTAGE CONTROLS.

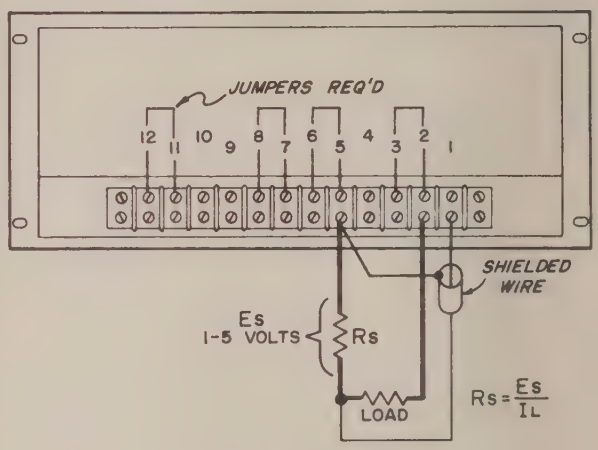
d. Where it is desired to add an external fine control having greater resolution than either the MAIN voltage control or VERNIER, or where remote control is desired, make connections shown in figure 2-13. Connect external control R_V and the capacitor as shown. The resistance of R_V should be sufficient to develop the sample voltage previously chosen, using the relevant programming constant.



NOTES:
1. USING CONSTANT VOLTAGE MAIN AND VERNIER FOR CURRENT CONTROL.
2. SET CONSTANT CURRENT MAIN AND VERNIER CONTROLS TO MAXIMUM.

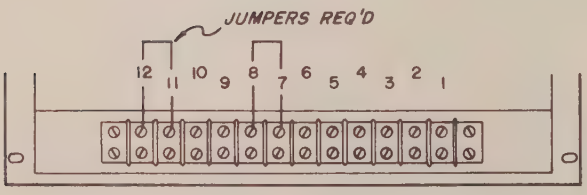


A. USING FRONT TERMINALS

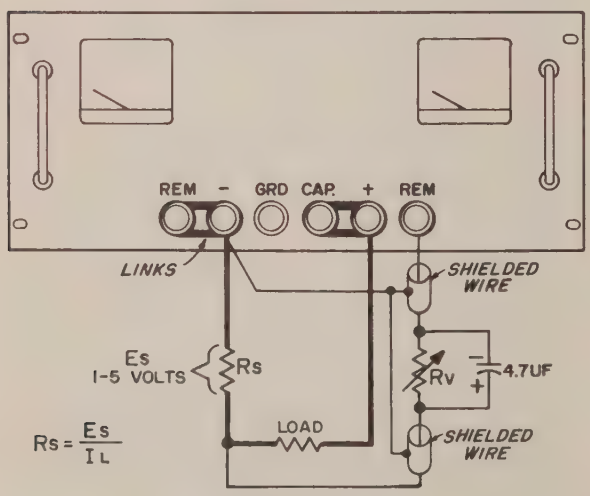


B. USING REAR TERMINALS

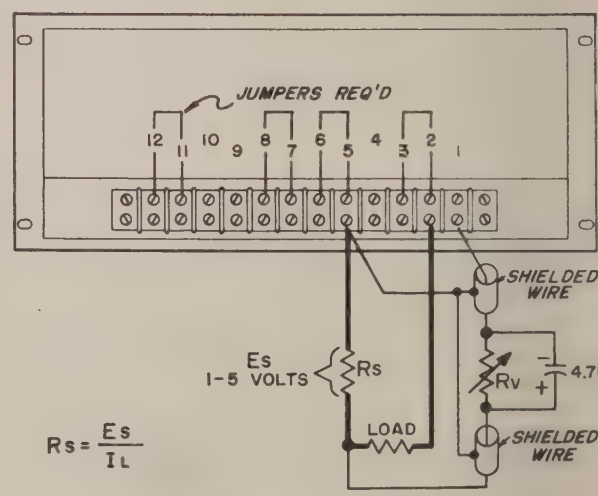
Figure 2-12. Constant-current, external conversion, local control.



NOTES:
1. SHORT OUT CONSTANT VOLTAGE MAIN AND VERNIER CONTROLS OR SET TO ZERO.
2. SET CONSTANT CURRENT MAIN AND VERNIER CONTROLS TO MAXIMUM.
3. Rv = CURRENT CONTROL 1000 Ω PER VOLT OF Es.



A. USING FRONT TERMINALS



B. USING REAR TERMINALS

Figure 2-13. Constant-current, external conversion, remote control

ELECTRONIC MEASUREMENTS CO.
EATONTOWN, NEW JERSEY

ADDENDUM NO. 135
(Manual Code S763)

INSTRUCTION MANUAL CHANGE

REGATRAN PVC POWER SUPPLY

Make the following changes in the instruction manual for the Regatran PVC Power Supply:

Page 15, paragraph 2-19. Delete paragraph 2-19 and substitute the following:

2-19. PARALLEL OPERATION. To operate two or more units in parallel, proceed as follows:

a. Make interconnections between units and load as shown in figure 2-15 (local sensing) or 2-16 (remote sensing). See diagrams, page 3 of this addendum. The wires to terminals 2 and 5 of all units must be of equal length and gauge to insure equal division of current.

NOTE

Use the connection to terminal 8 when it is anticipated that the required current output will be lower than the rated output of any one unit. If mainly constant-voltage operation is desired, eliminate the connections to terminals 8 and 9I. In this case, the current regulation will be degraded by a factor of N, where N is the number of units in parallel.

b. The CONSTANT CURRENT and CONSTANT VOLTAGE CONTROLS of all slave units may be set to any value; their setting has no effect on output when the units are connected in parallel.

c. For constant-voltage operation, set the master unit CONSTANT VOLTAGE CONTROLS for the required output voltage, and set the master CONSTANT CURRENT CONTROLS for the current output to be supplied by the master unit plus 10 percent of the rated current output of the master (total current will be N times reading on master, where N is number of units in parallel).

NOTE

Unless the safety provided by close limiting is required, the CONSTANT CURRENT CONTROLS may normally be set to maximum.

d. Adjust voltage by means of the master unit controls. For local control, regulation is obtained only at the master unit terminals.

e. For constant-current operation, set the master unit CONSTANT VOLTAGE CONTROLS for at least 1 volt above the expected maximum compliance voltage, and set the master CONSTANT CURRENT CONTROLS for the desired output current divided by the number of units in parallel.

Page 16, Figures 2-15 and 2-16. Delete figures 2-15 and 2-16 and substitute figures 2-15 and 2-16 as shown on page 3 of this addendum.

NOTE

In figure 2-16 (see page 3 of this addendum), the output capacitor must equal the total value of the output capacitors (C9) for all units. The internal capacitors may be removed from the units and used at the load.

Page 26, paragraph 4-13. Add paragraphs 4-13.1 and 4-13.2 after paragraph 4-13.

4-13.1. SERIES SYSTEM GROUP BALANCE. Adjust drive voltage as follows:

a. Connect a Variac in power supply ac input, and adjust input for 115 volts ac.

b. Connect a voltmeter negative lead to J3-1 and positive lead to J3-6.

c. With power supply controls set for maximum rated current and any output voltage, adjust drive-voltage-adjust potentiometer R44 for a voltmeter indication of 6.4 volts dc **(PVC60-15 only) or 7.4 volts dc (PVC36-30 only).**

4-13.2. SERIES SYSTEM DRIVE VOLTAGE ADJUSTMENT. If there is an unbalanced output during parallel operation, or if any series string transistor (Q201 through Q207) is replaced, perform adjustments in 4-13 and 4-13.1.

Page 30, figure 4-3. Add the following to figure 4-3:

	SYMPTOM	CAUSE	REMEDY
22.	Unbalanced output during parallel operation for constant voltage.	Improper adjustment of drive-voltage-adjust potentiometer R44.	Refer to paragraph 4-13 and 4-13.1.
		Improper wiring between units.	Rewire (refer to paragraph 2-19a and figures 2-15 and 2-16).

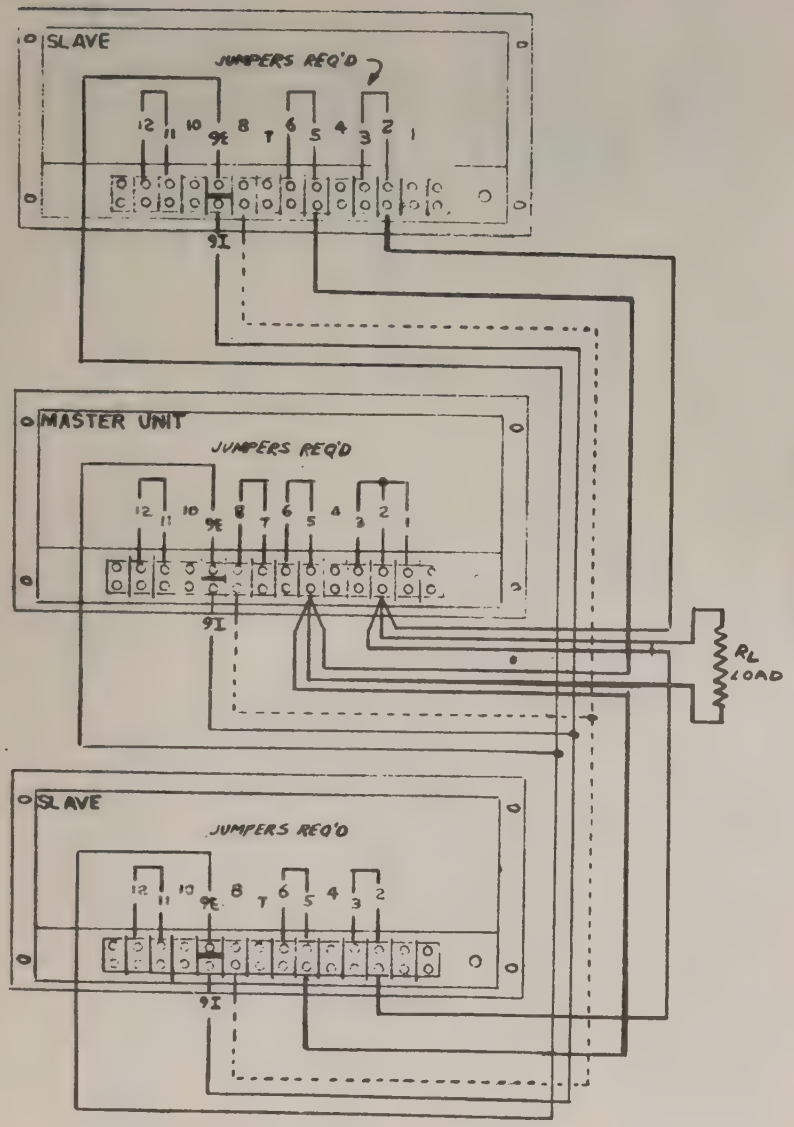


FIGURE 2-15. PARALLEL OPERATION, LOCAL CONTROL & SENSING

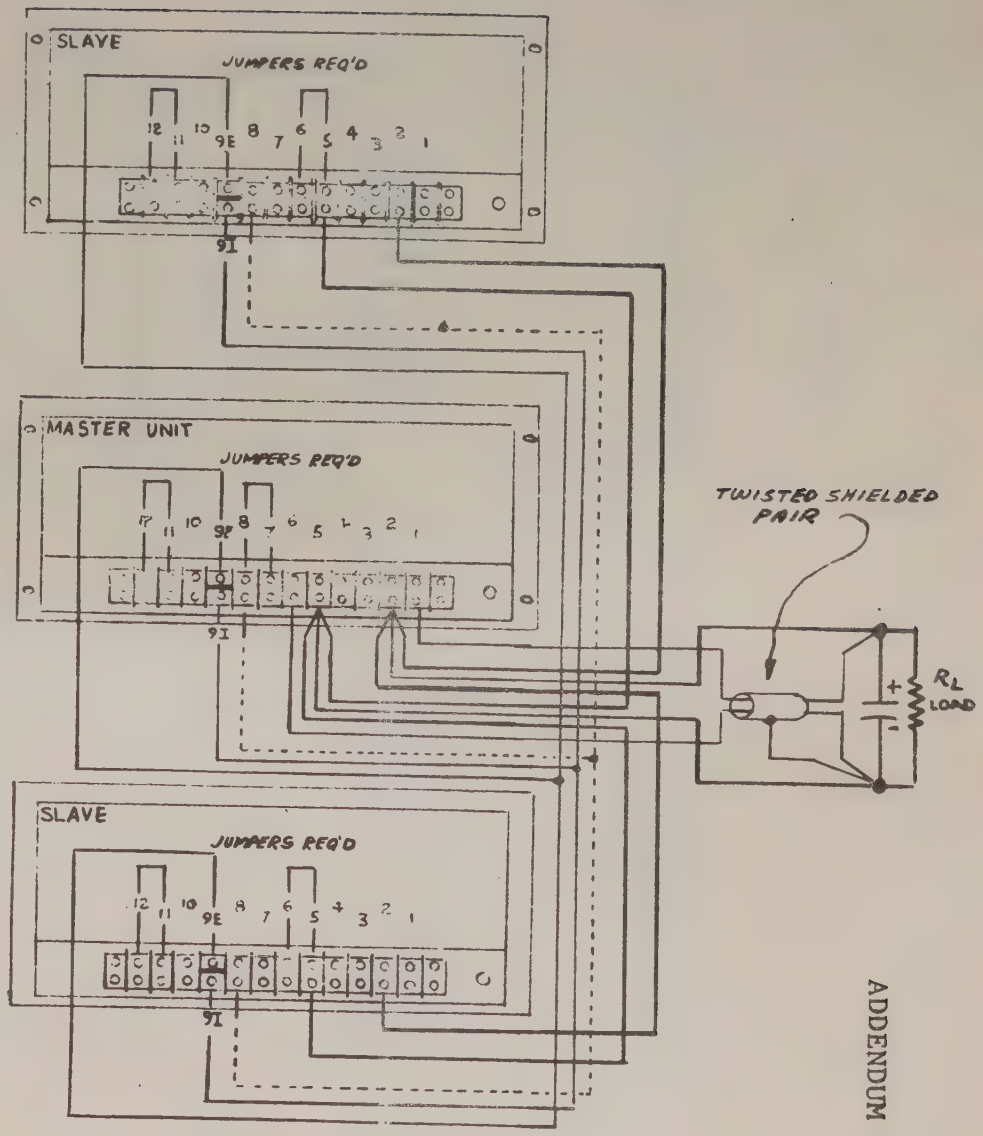


FIGURE 2-16. PARALLEL OPERATION LOCAL CONTROL AND REMOTE SENSING.

9/63
ADDENDUM NO. 135
(CONT)

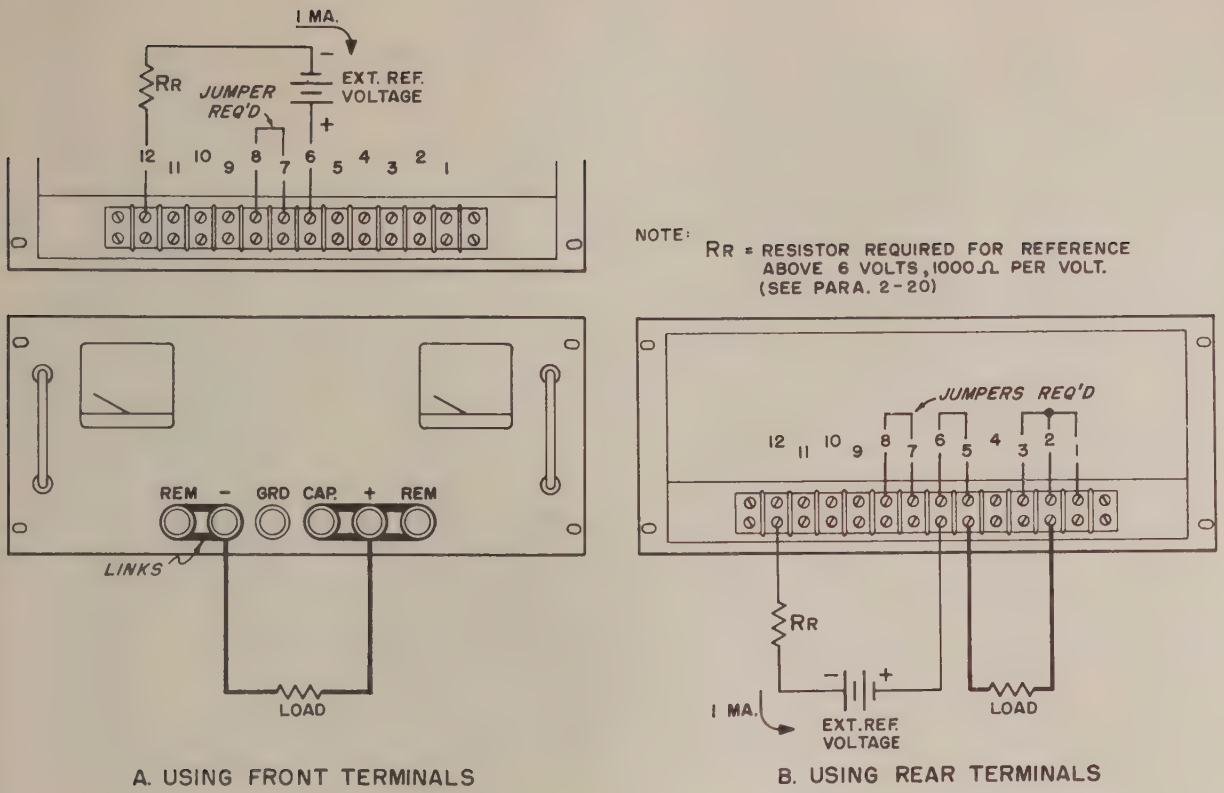

1 MA.
RR
JUMPER REQ'D
EXT. REF. VOLTAGE
12 11 10 9 8 7 6 5 4 3 2 1
REM - GRD CAP. + REM
LINKS
LOAD
NOTE: RR = RESISTOR REQUIRED FOR REFERENCE ABOVE 6 VOLTS, 1000Ω PER VOLT. (SEE PARA. 2-20)
JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
RR
1 MA.
EXT. REF. VOLTAGE
LOAD
A. USING FRONT TERMINALS
B. USING REAR TERMINALS

Figure 2-14. External reference .

e. The current may then be adjusted by the external control alone, or by means of the internal and external controls combined. This is left to the discretion of the user.

2-18. EXTERNAL REFERENCE VOLTAGE. An external reference voltage may be employed with all of the operating modes described in this section, providing the obvious logical limitations are observed. To use an external voltage, proceed as follows:

Note

The external reference source must be capable of supplying 1 milliampere.

a. Make connections shown in figure 2-14. It will be necessary to remove the link between terminals 11 and 12.

b. Select resistor R_R. The resistance should be 1000 ohms for each additional volt of reference voltage above 6 volts. The wattage is determined by the fact that this resistor must carry 1 milliampere.

2-19. PARALLEL OPERATION. To operate two or more units in parallel, proceed as follows:

a. Make interconnections between units and to load as shown in figure 2-15 or 2-16, depending on whether local sensing or remote sensing is desired.

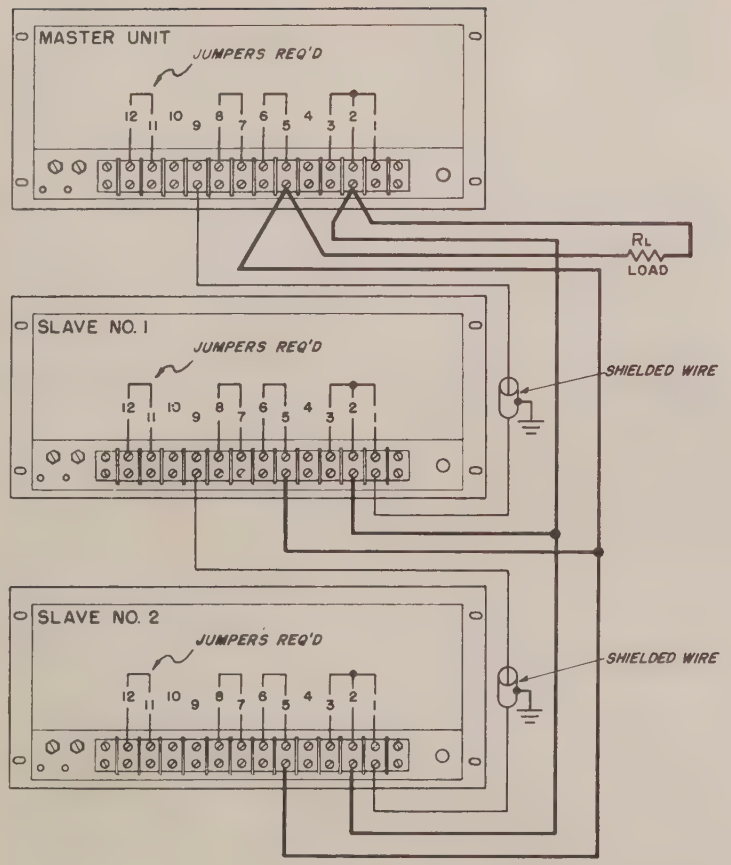
b. Set the CONSTANT CURRENT CONTROLS on all units so that the sum of their settings is 10 percent of rated current above the desired current, with the current equally shared among all units.

Note

Unless the safety provided by close limiting is actually required, the CONSTANT CURRENT CONTROLS MAY be normally set to maximum

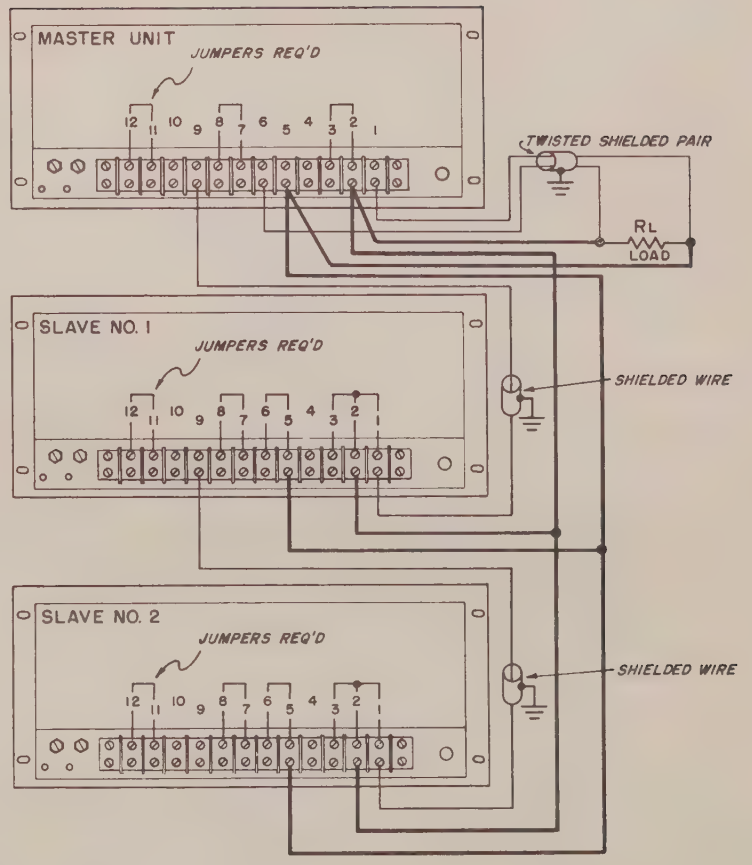
c. Set the CONSTANT VOLTAGE CONTROLS on all slave units to zero.

d. Adjust the voltage by means of the controls on the master unit. For local control, regulation is obtained only at the terminals of the master. (continued on page 18)



NOTES:
1. SET CONSTANT VOLTAGE MAIN AND VERNIER CONTROLS ON ALL SLAVE UNITS TO ZERO.
2. SET CONSTANT CURRENT MAIN AND VERNIER CONTROLS ON ALL SLAVE UNITS TO MAXIMUM.

Figure 2-15. Parallel operation, local control and local sensing.



NOTES:
1. SET CONSTANT VOLTAGE MAIN AND VERNIER CONTROLS ON ALL SLAVE UNITS TO ZERO.
2. SET CONSTANT CURRENT MAIN AND VERNIER CONTROLS ON ALL SLAVE UNITS TO MAXIMUM.

Figure 2-16. Parallel operation, local control and remote sensing.

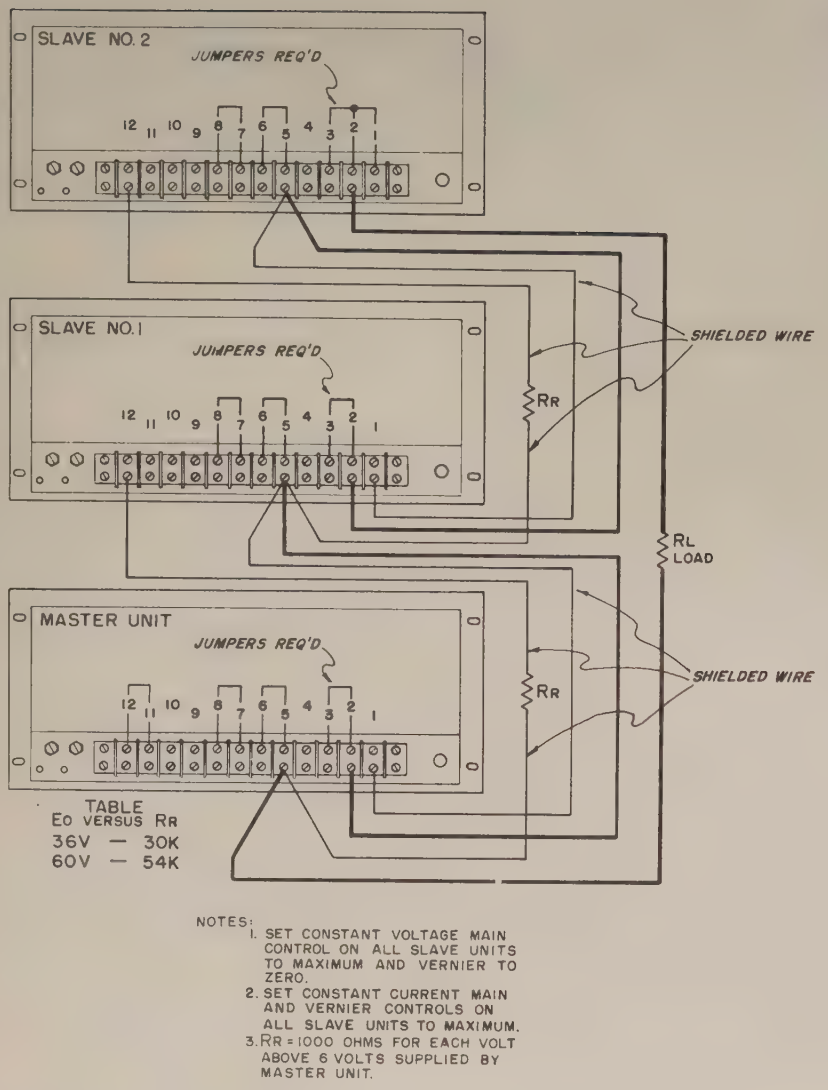

SLAVE NO. 2
JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
SLAVE NO. 1
JUMPERS REQ'D
MASTER UNIT
JUMPERS REQ'D
SHIELDED WIRE
SHIELDED WIRE
RR
RR
RR
RL
LOAD
TABLE
Eo VERSUS RR
36V — 30K
60V — 54K
NOTES:
1. SET CONSTANT VOLTAGE MAIN CONTROL ON ALL SLAVE UNITS TO MAXIMUM AND VERNIER TO ZERO.
2. SET CONSTANT CURRENT MAIN AND VERNIER CONTROLS ON ALL SLAVE UNITS TO MAXIMUM.
3. RR = 1000 OHMS FOR EACH VOLT ABOVE 6 VOLTS SUPPLIED BY MASTER UNIT.

Figure 2-17. Series operation, local control and local sensing.

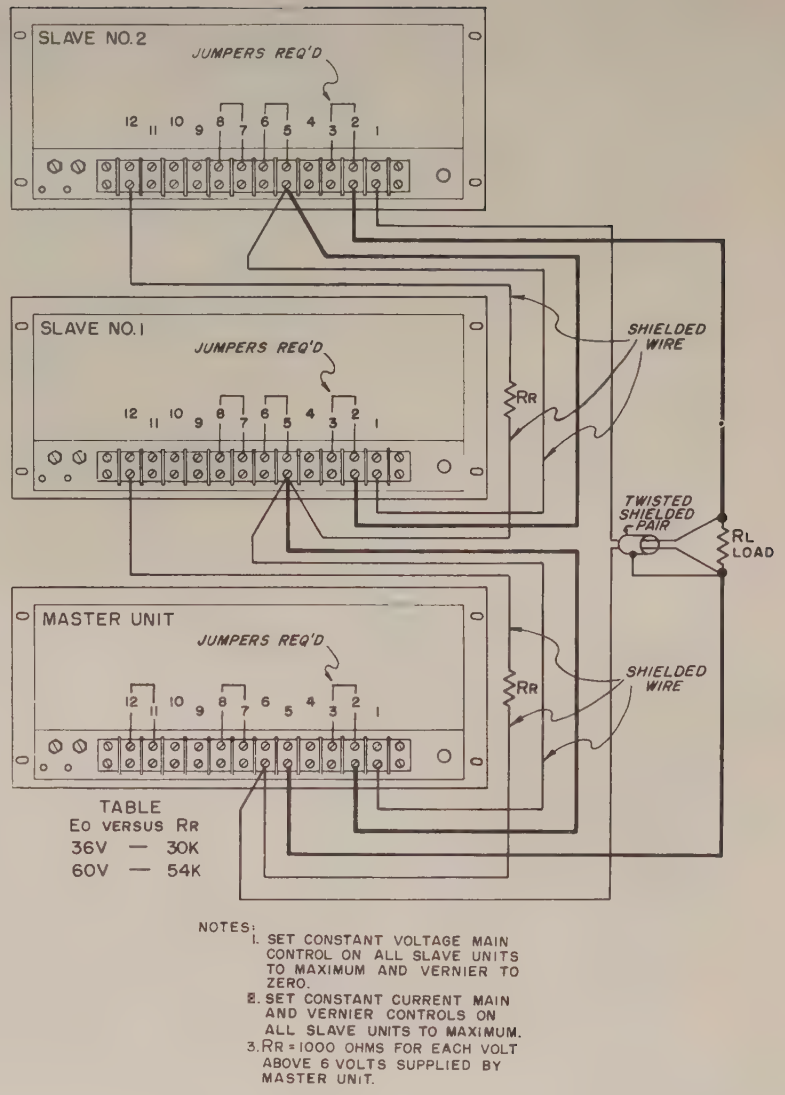

SLAVE NO. 2
JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
SLAVE NO. 1
JUMPERS REQ'D
MASTER UNIT
JUMPERS REQ'D
SHIELDED WIRE
SHIELDED WIRE
TWISTED SHIELDED PAIR
RR
RR
RR
RL
LOAD
TABLE
Eo VERSUS RR
36V — 30K
60V — 54K
NOTES:
1. SET CONSTANT VOLTAGE MAIN CONTROL ON ALL SLAVE UNITS TO MAXIMUM AND VERNIER TO ZERO.
2. SET CONSTANT CURRENT MAIN AND VERNIER CONTROLS ON ALL SLAVE UNITS TO MAXIMUM.
3. RR = 1000 OHMS FOR EACH VOLT ABOVE 6 VOLTS SUPPLIED BY MASTER UNIT.

Figure 2-18. Series operation, local control and remote sensing.

Note

In the constant current mode, the total output current is the sum of all outputs; hence, adjustment from zero to full sum requires use of current controls on all units.

2-20. SERIES OPERATION. To operate two or more units in series, proceed as follows:

a. Make connections shown in figure 2-17 or 2-18, depending on whether local sensing or remote sensing is desired. Resistor R_R should be of a stable wire-wound type and should be selected from the table in figure 2-17 or 2-18.

b. Set the voltage and current controls on all slave units to maximum (fully clockwise).

c. Turn all units on, and then adjust the total output voltage by means of the controls on the master. It may be necessary to change the setting of the VOLTAGE CAL control of the slave in order to obtain the correct output voltage.

Note

It is obvious that all of the various connections described above for single units may be employed for slave units (series or parallel). However, the number of combinations is so large as to lead to an endless variety of diagrams. The operator can use other diagrams previously described, plus his own ingenuity. If additional assistance is required, consult a local representative or the factory.

SECTION III
CIRCUITRY

Note

Unless otherwise indicated, circuit references are made to the schematic diagram.

3-1. GENERAL. Major functional sections of this power supply include: full-wave rectifiers for the main dc output and for dc potentials employed within the unit; a silicon controlled rectifier (SCR) preregulator system; a series (pass) transistor and driver system; two independent control systems, one for constant-voltage and one for constant-current; and a stable reference voltage source and reference regulator. A simplified block diagram of the power supply is shown in figure 3-1.

An emitter coupled balanced detector continuously compares the output voltage with a stable reference voltage. A second, and completely separate detector system compares a fraction of the reference voltage against a sample voltage resulting from output current. Separate high gain amplifiers drive the series system, and result in exceedingly small error voltages at equilibrium. A third control system maintains the input voltage at a value such as to limit the series system dissipation. This latter system employs silicon controlled rectifier(s) which in some models also serve as the main rectifiers.

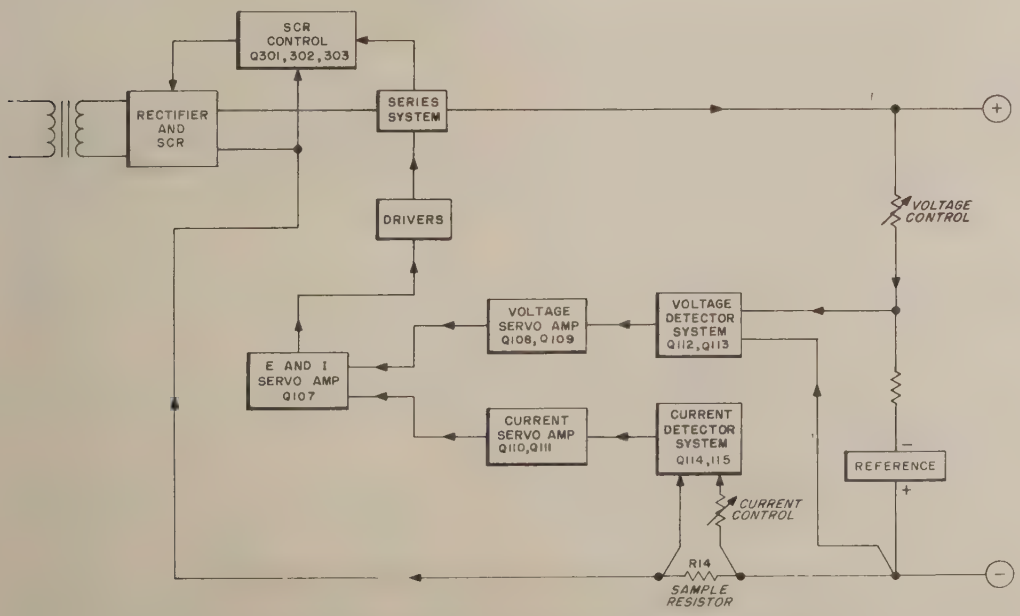


Figure 3-1. Series PVC block diagram.

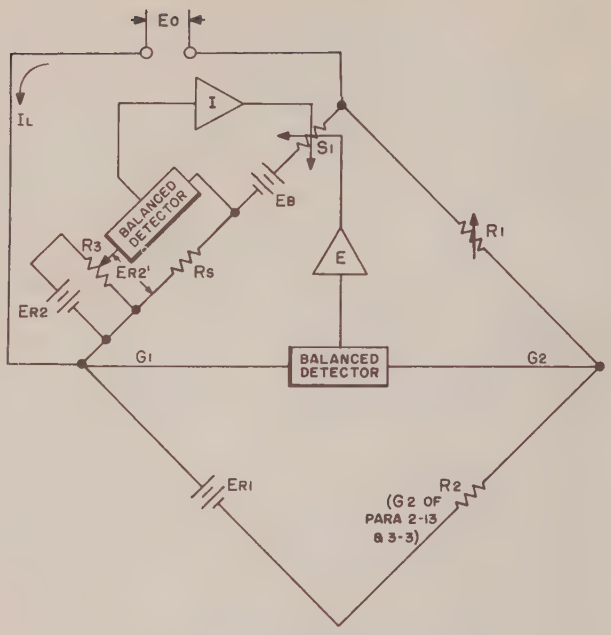


Figure 3-2. Output control systems.

3-2. VOLTAGE AND CURRENT CONTROL SYSTEMS, LOCAL AND PROGRAMMED. Figures 3-2 illustrated the output voltage and output current control systems in a common simplified form for local controlled or programmed operation of the power supply.

For voltage control, E_o is the regulated output voltage controlled by series element S_1, E_B is a source of unregulated voltage, E_{R1} is a stable reference potential, R_1 is a control resistor, and R_2 is a fixed resistor. When inputs G_1 and G_2 are equal, that is, with the balanced input detector (refer to paragraph 3-5) at equilibrium, then

$$\frac{E_o}{E_R} = \frac{R_1}{R_2} \quad \text{and} \quad E_o = E_R \times \frac{R_1}{R_2}$$

Since E_R and R_2 are constant, then $E_o = KR_1$; thus the output voltage is dependent only upon the value of R_1, which, in the power supply, consists of CONSTANT VOLTAGE CONTROLS R6 and R7 in local use. For programmed operation, an external control resistor is placed in series with the internal controls.

For current control, R_3 is a control resistor, R_S is a fixed sample resistor in series with the load, and E_{R2} is a stable reference potential. The current control system functions to maintain the voltage drop, due to the load current in the sample resistor, constant at some specific value. Thus, if the voltage is held constant, and the sample resistor remains fixed, then the load current must be constant. In local operation of the power supply, R_3 consists of CONSTANT CURRENT CONTROLS R12 and R13. For programmed operation, an external control resistor is placed in series with the internal controls.

3-3. VOLTAGE CONTROL SYSTEM, MHOGRAMMED. For Mhogrammed operation, resistor R_1 (figure 3-2) is held constant and the conductance, $g_2 = \frac{1}{R_2}$, provides the control. The control equation is then

$$E_o = E_{max} \times \frac{g_2}{g_k}$$ (refer to paragraph 2-13),

which, expressed in terms of resistance, is

$$E_o = \frac{E_R R_1}{R_2} .$$

For any E_o, $R_2 = \frac{E_R}{E_o} \times R_1$.

3-4. MAIN SUPPLIES. Transformer T1 together with associated rectifier diodes, silicon controlled rectifier (SCR), and filter elements consisting of a choke and capacitors provide a filtered controlled voltage for the main series system. Transformer T3 together with associated rectifier and filter elements provide the series section bias, and the positive operating potentials for the series transistor and driver system.

3-5. CONTROL SYSTEMS. The control systems in this power supply consist of three main servo loops (not including the subsidiary systems, such as in the main reference voltage), as follows:

a. SCR system which controls input to the final regulator system.

b. Voltage amplifier system starting with Q112 and Q113.

c. Current amplifier system starting with Q114 and Q115.

3-6. MAIN AMPLIFIER. A fraction of the output voltage is compared against a fixed reference voltage for voltage regulation. A fraction of the reference voltage is compared against a sample voltage resulting from current

for current regulation. At exact null the error at the input of both detector systems would be zero; however, as in any servo system there is a finite error which is passed by the detector to additional amplifiers. Thus, the error is amplified and then employed to drive the series system, which acts as a variable conductance in series with the load to maintain a constant output voltage, or a constant output current. As in any servo system, at equilibrium the error is just sufficient to drive the correction system to the point which just permits the aforementioned amount of error. This of course depends on the gain of the system. The series system may be driven at one of two inputs by detector system Q112 and Q113, or by detector system Q114 and Q115, and associated amplifier. When the current through the CONSTANT CURRENT CONTROLS, R12 and R13, is sufficient to overcome the reference bias in the current detector circuit, the current control loop is energized and overcomes the voltage control loop. At this point the current control system maintains a constant current output rather than a constant voltage.

3-7. REFERENCE SYSTEM. The reference system consists of an auxiliary regulator which operates from reference diodes CR104 and CR105. Input stage Q104 and Q105 operate as a detector, and together with amplifier Q102 and Q103 and series system Q101, provide highly regulated outputs of approximately -6 and -12 volts. In addition, the reference section provides stabilized positive 6 volts bias for the amplifier system.

3-8. SCR CONTROL. Transistors Q301, Q302, and Q303 provide an SCR control system designed to deliver controlled voltage for the final regulator system. Q301 serves as the input, Q302 as a driver, and Q303 as a regulator. Control R312 is used to set the voltage at low output voltages, and R309 is used to adjust the voltage at high output voltages.

SECTION IV

MAINTENANCE

Note

Attention is called to the Warranty under which this equipment is sold, printed on the front inside cover of this instruction manual.

4-1. PARTS REPLACEMENT. In general, replacement parts are completely defined by the values and tolerances indicated on the parts list which accompanies the schematic diagram. The following components, however, require special attention in replacement:

a. Q107, Q108, Q114, and Q115. Replacement will affect null adjustments, which should therefore be readjusted in accordance with paragraph 4-3. Occasionally these transistors may require selection to avoid excessive unbalance.

b. CR105 and CR106. Replacement may affect the reference voltage, which will require recalibration of the power supply in accordance with paragraphs 4-5 and 4-8.

c. MAIN and VERNIER controls. If any of these wire-wound potentiometers is defective, it is advisable to obtain an exact replacement. If none is available locally, an order should be addressed to the factory, giving the exact part number from the parts list. Any temporary substitute for the VERNIER potentiometers or the MAIN current potentiometer should operate through an arc of 280 degrees (effective electrical rotation) for the panel dial markings to represent the output correctly. A substitute for the MAIN voltage potentiometer requires an effective electrical rotation of 315 degrees.

d. C9. Output capacitor C9 and any other capacitor shunted across C9 require replacement by the exact part number to insure proper operation of this power supply. No "equivalents" should be used.

4-2. EM TYPE NUMBERS. Replacement parts bearing EM type numbers must be ordered from Electronic Measurements Company of Red Bank, Eatontown, New Jersey.

4-3. VOLTAGE NULL ADJUSTMENT. The VOLTAGE NULL screwdriver adjust control, located on the rear apron, permits adjustment of the balanced input detector in the voltage control system to zero level. This adjustment requires a voltmeter having a full scale sensitivity of 2.5 volts or less. Adjustment is made as follows:

a. Place the power supply in operation at any voltage.

b. Connect the voltmeter between TP1 and TP2, located on the rear apron adjacent to the VOLTAGE NULL control.

c. Remove the acorn nut covering the VOLTAGE NULL control.

d. Adjust the VOLTAGE NULL control to obtain a zero indication on the voltmeter. A very sensitive indication may be obtained by alternately connecting and disconnecting the meter lead.

Note

If null cannot be obtained, interchange Q112 and Q113.

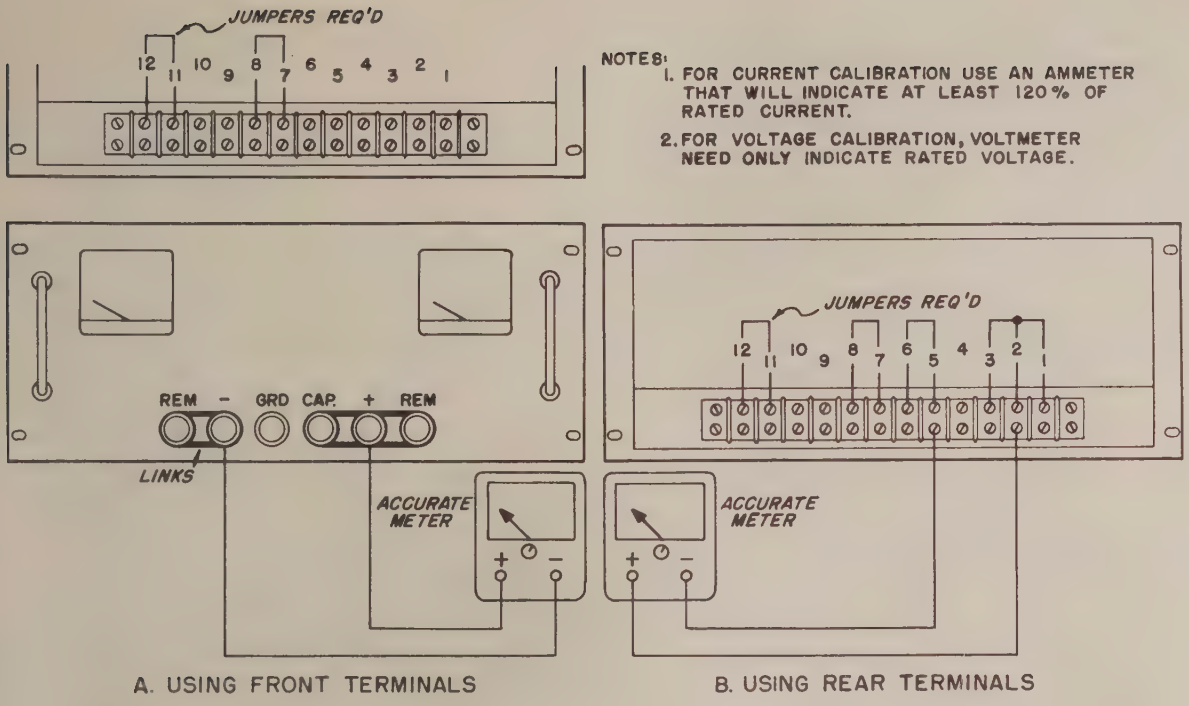

JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
NOTES:
1. FOR CURRENT CALIBRATION USE AN AMMETER THAT WILL INDICATE AT LEAST 120% OF RATED CURRENT.
2. FOR VOLTAGE CALIBRATION, VOLTMETER NEED ONLY INDICATE RATED VOLTAGE.
REM - GRD CAP. + REM
LINKS
ACCURATE METER
+ -
JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
ACCURATE METER
+ -
A. USING FRONT TERMINALS
B. USING REAR TERMINALS

Figure 4-1. Voltage calibration with accurate voltmeter

4-4. CURRENT NULL ADJUSTMENT. The CURRENT NULL screwdriver adjust control, also located on the rear apron, permits adjustment of the output current to zero. Adjustment is made as follows:

a. Place the power supply in operation.

b. Set the MAIN voltage control to one-half of rated output.

c. Set the CONSTANT CURRENT CONTROLS to zero.

d. Connect an ammeter, with a full scale sensitivity of 1 ampere, between the + and - output terminals.

CAUTION

If a malfunction should be present, it is possible at this point that the current may rise to a high value and damage the external ammeter.

e. Remove acorn nut covering the CURRENT NULL control.

f. Adjust the CURRENT NULL control to obtain a zero indication on the ammeter.

Note

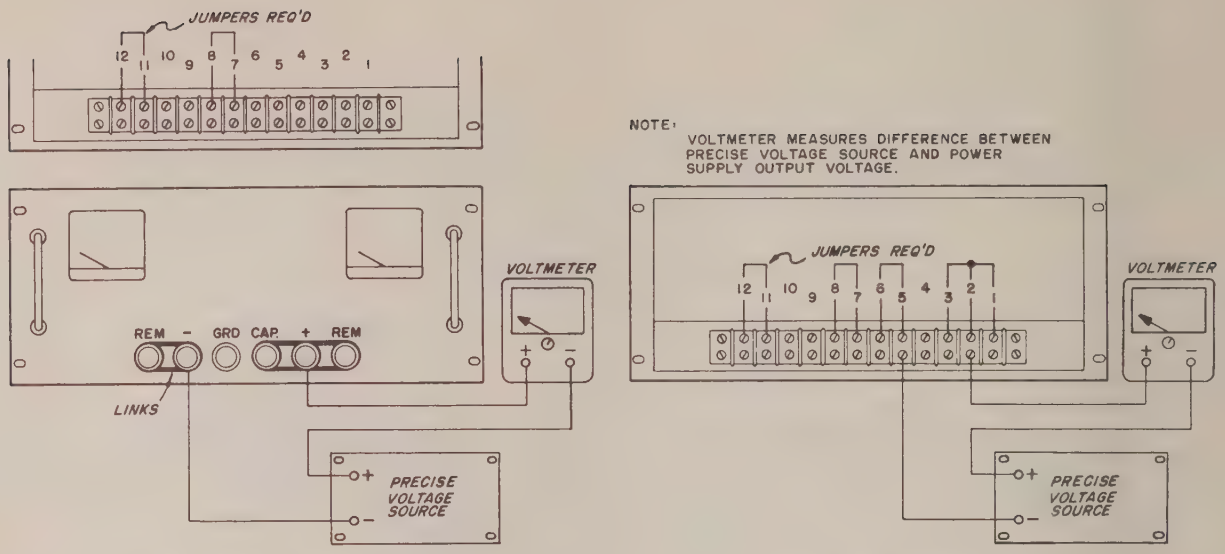
If null cannot be obtained, interchange Q114 and Q115.

4-5. VOLTAGE CALIBRATION. The VOLTAGE CAL screwdriver adjust control, located on the rear apron, permits adjustment for close agreement between panel markings and output, or to provide precise remote control at the nominal ohms-per-volt programming constant. This adjustment can be performed with either an accurate voltmeter alone or a voltmeter and an external precise source of voltage.

4-6. CALIBRATION WITH ACCURATE VOLTMETER. If an accurate voltmeter only is employed, proceed as follows:

a. Make connections shown in figure 4-1. Remove the acorn nut covering the VOLTAGE CAL control.

b. Calibration to Panel Markings. Place the unit in local operation. Remove the MAIN and VERNIER voltage control knobs. Rotate each shaft, in turn, from the extreme counter-clockwise position until the output voltage just starts to increase from zero. Set the shafts as close as possible to zero. At this point, slide the knobs onto the shafts so that their pointers


JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
VOLTMETER
REM - GRD CAP + REM
LINKS
PRECISE VOLTAGE SOURCE
NOTE:
VOLTMETER MEASURES DIFFERENCE BETWEEN PRECISE VOLTAGE SOURCE AND POWER SUPPLY OUTPUT VOLTAGE.
JUMPERS REQ'D
12 11 10 9 8 7 6 5 4 3 2 1
VOLTMETER
PRECISE VOLTAGE SOURCE

A. USING FRONT TERMINALS

B. USING REAR TERMINALS

Figure 4-2. Voltage calibration with external precise source of voltage.

line up with the zero markings on the panel. Tighten all setscrews, making certain that each shaft position was not disturbed. Set the MAIN voltage control to the maximum rated voltage and adjust the VOLTAGE CAL control for that voltage on the external voltmeter. It may be necessary to short or remove shorts from fixed trimmer resistors R128 and R129, which are in series with the VOLTAGE CAL control. Check the VERNIER for proper operation over its range.

c. Calibration to Exact Nominal Ohms-Per-Volt Programming Constant. Set the MAIN and VERNIER voltage controls at zero. Place the power supply in programmed operation with an external control resistor of known accuracy which will develop maximum rated voltage, and adjust the VOLTAGE CAL control for that voltage on the external meter. It may be necessary to short or remove shorts from fixed trimmer resistors R128 and R129.

4-7. CALIBRATION WITH EXTERNAL PRECISE SOURCE OF VOLTAGE. If an external precise source of voltage is available, proceed as follows:

a. Make connections shown in figure 4-2.

b. Calibration to Panel Markings. Zero the MAIN and VERNIER voltage controls as directed in step b, paragraph 4-6. Set the MAIN voltage control to maximum rated voltage, and set the external source for precisely the same voltage. Adjust the VOLTAGE CAL control for zero indication on the external voltmeter, using the lowest dc meter range available. It may be necessary to short or remove shorts from fixed trimmer resistors R128 and R129, which are in series with the VOLTAGE CAL control. Check the VERNIER for proper operation over its range.

c. Calibration to Exact Nominal Ohms-Per-Volt Programming Constant. Place the power supply in programmed operation with an external control resistor of known accuracy which will develop maximum rated voltage. Set the external source for the same voltage. Adjust the VOLTAGE CAL control for zero indication on the external voltmeter, using the lowest dc range available. It may be necessary to short or remove shorts from fixed trimmer resistor R128 and R129.

4-8. CURRENT CALIBRATION. Calibration of the current output is possible by one of three principal methods.

a. Calibration in accordance with paragraph 4-9 to provide close agreement between panel markings and output.

b. Calibration in accordance with paragraph 4-10 to provide an exact programming constant in ohms-per-percentage of rated current output when employing the linear-with-resistance programming method described in paragraph 2-15.

c. Calibration (paragraph 4-11) when employing the linear-with-conductance programming method described in paragraph 2-17.

4-9. CALIBRATION TO PANEL MARKINGS. To calibrate so as to provide agreement with panel markings, proceed as follows:

a. Set all controls to zero and connect an accurate ammeter, capable of indicating maximum rated current, between the + and - output terminals of the unit.

b. Set the MAIN voltage control to one-half rated voltage.

c. Turn the power supply on and remove the MAIN and VERNIER current control knobs.

d. While observing the external ammeter, rotate each shaft, in turn, until the instant a current rise from the minimum setting occurs. Then turn the shafts counterclockwise until the meter just indicates the minimum current. At this point, slide the knobs onto the shafts so that their pointers line up with the minimum panel markings. Tighten all setscrews, making certain that each shaft position was not disturbed.

e. Set the MAIN current control to maximum calibration and adjust the CURRENT CAL control until the maximum rated current is indicated on the ammeter.

f. Check the VERNIER for proper operation over its range.

4-10. CALIBRATION FOR EXACT OHMS-PER-PERCENTAGE OF RATED CURRENT PROGRAMMING CONSTANT. To calibrate so as to provide an exact ohms-per-percentage of rated current programming constant, proceed as follows:

a. Make connections shown in figure 2-10, with the ammeter substituting for the load resistor.

b. Set the CONSTANT VOLTAGE CONTROLS to one-half rated voltage, and set the CONSTANT CURRENT CONTROLS to zero.

c. Set R_C to exactly 100 ohms, and adjust the CURRENT CAL control until the ammeter indicates maximum rated current. The current may be programmed from zero to maximum by a fractional selection of the resistance of R_C.

4-11. CALIBRATION FOR LINEAR-WITH-CONDUCTANCE PROGRAMMING. The amperes-per-mho programming constant will depend upon the internal sample resistor, and therefore, since this resistor has a 10 percent tolerance, the constant will vary from unit to unit. It is recommended that if this method of programming is employed, external sample resistors should be selected for each desired current, with the internal resistor serving for maximum rated current.

4-12. SERIES SYSTEM VOLTAGE ADJUSTMENT. To perform this adjustment, proceed as follows:

a. Remove the cover for access to the printed circuit boards.

b. Connect a voltmeter, with a full scale sensitivity of approximately 20 volts, between the positive output terminal and the positive terminal on capacitor C4.

c. Turn the power supply on, using nominal line voltage. Rotate the CONSTANT CURRENT CONTROLS fully clockwise (maximum current). Set the output to some low voltage in the 3-volt range, and adjust the load for maximum rated current.

d. Adjust R312, located on the SCR control card, to obtain a ~~6.5~~ 5.5-volt indication on the meter. For maximum load line drop or rapidly pulsed loads, consult factory for further adjustments.

e. Set the power supply to maximum rated voltage and current.

f. Adjust R309, also located on the SCR control card, to obtain ~~6.5~~ 5.5 volts.

CAUTION

Certain adjustment combinations of R309 and R312 will prevent proper operation of the power supply. If difficulty is encountered in the above adjustments, start with both controls in the approximate center position of their range.

Note

R312 must always be set before R309.

4-13. SERIES SYSTEM BALANCE ADJUSTMENT. To perform this adjustment proceed as follows:

a. Set all balance adjusting rheostats (see figure 5-1) to zero ohms (fully clockwise).

b. Place the power supply in operation with rated output current and one-half rated output voltage.

c. Using a voltmeter with a full scale sensitivity of approximately 1 volt, note and record the voltage drop across each emitter resistor (see figure 5-1).

d. Add the recorded voltages and divide by the total number of emitter resistors to obtain an average voltage.

e. Starting with the highest recorded voltage, adjust each rheostat, in turn, to obtain the same average voltage across each emitter resistor.

f. Repeat step e, above, until the same voltage appears across each resistor.

4-14. ADJUSTMENT OF R106, R110, R111, AND R112. These controls, which are factory preset, help shape the phase-gain characteristics of the regulator amplifiers. They normally require no adjustment. If replacement of parts or extremes of service cause such severe changes as to result in loop instability, the power supply should be returned to the factory.

4-15. FREQUENCY OF ADJUSTMENTS. Internal controls normally require adjustment at intervals no more frequent than one year in most applications. However, it is evident that, depending on the stringency of accuracy and stability limits in any application, these controls may require more frequent adjustment.

4-16. LOCALIZATION OF SERIES TRANSISTOR FAILURE. Normally the series system is long-lived and free from failure. However, if an output voltage appears on the panel meter with controls turned to zero and switches or circuit breakers on, it is probable that a series transistor has failed. To localize the failure, proceed as follows:

a. Turn the power supply off and remove the series system assembly.

b. Measure the resistance from each sink plate (one or more) to the emitter bus of the attached transistors. If a short is indicated, reverse the meter leads and remeasure. If the short persits it may be assumed that one of the series transistors has failed.

c. To localize the defective transistor, measure the resistance from collector to emitter of each transistor, using both possible ohmmeter connections (normal resistance is 0. 1 ohm or less). Any transistor measuring short for both connections is defective.

d. Disconnect the emitter lead of the suspected transistor and recheck collector to emitter resistance to varify original finding. Also recheck sink(s) for additional shorts.

4-17. VOLTAGE MEASUREMENTS. The voltages shown on the schematic diagram were measured in one production unit and therefore indicate only the general range of values to be expected. Some measured voltages may, in fact, depart from these values by as much as 25 percent without causing difficulty.

4-18. TROUBLE SHOOTING TABLE. Listed in the trouble shooting table, figure 4-3, are possible symptoms of troubles, with their probable causes and remedies. The table is intended as a brief guide in trouble shooting. It is best employed in conjunction with the voltages shown on the schematic diagram, particularly when more obvious causes of malfunction have been eliminated and the fault is presumed to lie somewhere in a detailed circuit defect.

Figure 4-3. Trouble shooting table.

SYMPTOM	CAUSE	REMEDY
1. Unit inoperative, or circuit breaker CB1 trips repeatedly.	a. Circuit breaker CB1 defective.	a. Replace.
	b. Transformer T1 or T3 shorted.	b. Replace.
	c. Capacitor C4, or any capacitor in parallel with it, shorted.	c. Replace defective capacitor.
	d. Rectifier CR8 or CR9 (where used) shorted.	d. Replace defective rectifier.
	e. SCR Q1 or Q2 shorted.	e. Replace defective SCR.
	f. Rectifier CR3 or CR4, or capacitor C3, defective.	f. Replace defective component.
2. No dc output to load.	a. Output capacitor C9, or any capacitor in parallel with it, shorted.	a. Replace defective capacitor.
	b. Rectifier CR8 or CR9 (where used) open.	b. Replace defective rectifier.
	c. Resistor R117, R118, or R119, or VOLTAGE CAL control R8 open.	c. Replace defective component.
	d. Transistor Q107, Q108, Q109, Q110, Q111, Q112, Q113, Q114, or Q115 defective.	d. Replace defective transistor.
	e. CURRENT CAL control R10 open.	e. Replace.
	f. Feedback capacitor C107 or diode CR116 shorted.	f. Replace defective component.
	g. Reference voltage failure.	g. Refer to symptom 20.
	h. Circuit breaker CB2 defective.	h. Replace.
	i. Detailed circuit defect.	i. Make voltage or current measurements, as required, to detect trouble.
3. Voltmeter indication different from control settings at full output during voltage operation.	a. Not calibrated.	a. Recalibrate (refer to paragraphs 4-5 through 4-7).
	b. Reference section defective.	b. Refer to symptoms 18 through 21.

Figure 4-3. Trouble shooting table (Cont.)

SYMPTOM	CAUSE	REMEDY
4. Ammeter indication different from control settings at full output during current operation.	a. Not calibrated.	a. Recalibrate (refer to paragraphs 4-8 through 4-10).
	b. Reference section defective.	b. Refer to symptoms 18 through 21.
5. No voltage control.	a. If no load connected, MAIN voltage control R6 or voltage VERNIER R7 may be open.	a. Replace defective component.
	b. If no load connected, series transistor system may be shorted.	b. Check series system.
	c. If no load connected, driver transistor may be shorted.	c. Check and replace defective transistor.
	d. Detailed circuit defect in voltage amplifier.	d. Make voltage measurements to detect defect.
6. No current control.	a. Defective MAIN current control R12, current VERNIER R13, or CURRENT NULL control R11.	a. Replace defective component.
	b. Series transistor system may be shorted.	b. Check and replace defective transistor.
	c. Detailed circuit defect in current amplifier.	c. Make current measurements to detect defect.
	d. Driver transistor may be shorted.	d. Check and replace defective transistor.
7. Poor line regulation (voltage or current).	a. Defective Zener diode CR105.	a. Replace.
	b. Defective reference section.	b. Refer to symptoms 18 through 21.
8. Poor load regulation (voltage or current).	a. Poor load connections or high resistance in load leads.	a. Check load connections.
	b. Detailed circuit defect.	b. Make voltage measurements to detect defect.
9. Excessive ripple.	a. Output capacitor C9 open.	a. Replace.
	b. For ripple voltage only, feedback capacitor C107 open.	b. Replace.
	c. Filter capacitor C8, C10, or C101 defective.	c. Replace defective capacitor.

Figure 4-3. Trouble shooting table (Cont.)

SYMPTOM	CAUSE	REMEDY
9. (Continued)	d. External control resistor and control line are coupling stray ac signal to unit.	d. Shield external control resistor and/or line.
10. Dc output contains low-frequency random noise in low millivolt region.	a. Noisy Zener diode CR103, CR104, or CR105.	a. Check for noise and replace defective Zener diode.
11. Loop instability.	a. Adjustment of R106, R110, R111, or R112 required.	a. Refer to paragraph 4-14.
	b. Defective resistor R106, R110, R111, or R112; or capacitor C103, C104, C105, C106, C201, or C9.	b. Replace defective component.
	c. Improper connections, grounding, or shielding of load lines and/or sensing lines.	c. Refer to operation instructions to check.
12. Excessive series voltage.	a. Adjustment of R309 and R312 required.	a. Refer to paragraph 4-12.
	b. SCR Q1 or Q2 shorted.	b. Replace defective SCR.
	c. Defective component in SCR control circuit.	c. Replace SCR control.
13. Deficient series voltage.	a. Adjustment of R309 and R312 required.	a. Refer to paragraph 4-12.
	b. SCR Q1 or Q2 open.	b. Replace defective SCR.
	c. SCR control transformer open.	c. Replace.
	d. Defective component in SCR control circuit.	d. Replace SCR control.
14. Satisfactory VOLTAGE NULL adjustment impossible.	a. Defective Zener diode CR103.	a. Replace.
	b. Defective reference section.	b. Refer to symptoms 18 through 21.
	c. Open NULL control R9.	c. Replace.
	d. Extreme mismatch of Q112 and Q113.	d. Replace transistors.
15. Satisfactory CURRENT NULL adjustment impossible.	a. Defective CURRENT NULL control R11, diode CR106, or transistor Q116.	a. Replace defective component.

Figure 4-3. Trouble shooting table (Cont.)

SYMPTOM	CAUSE	REMEDY
15. (Continued)	b. Mismatch of Q114 and Q115.	b. Replace transistors.
	c. Defective reference section.	c. Refer to symptoms 18 through 21.
16. Satisfactory VOLTAGE CAL adjustment impossible.	a. Defective reference section.	a. Refer to symptoms 18 through 21.
	b. Defective resistor R6, R7, R8, R117, R118, or R119.	b. Replace defective resistor.
17. Satisfactory CURRENT CAL adjustment impossible.	a. Defective reference section.	a. Refer to symptoms 18 through 21.
	b. Defective CURRENT CAL control R10.	b. Replace.
18. Excessive reference voltage.	a. Shorted Q101, Q102, Q103, or Q104.	a. Replace defective transistor.
	b. Open Q105	b. Replace.
19. Deficient reference voltage.	a. Open Q101, Q102, Q103, or Q104.	a. Replace defective transistor.
20. Zero reference voltage.	a. Shorted Q105.	a. Replace.
21. Excessive ripple noise in reference voltage (above 3 millivolts).	a. Defective Zener diode CR104 or CR105, or capacitor C101 or C102.	a. Replace defective component.

SECTION V
PARTS LIST AND DIAGRAMS

5-1. PARTS LIST. An electrical parts list is provided in this section to facilitate replacement of defective parts. The list includes recommended spares in quantity of one per reference symbol, except fuses, which are three per reference symbol. These parts are identified on the list by means of an *asterisk. When electrolytic capacitors are to be stored as spares for one year or more, request Technical Note 32. Part numbers are indicative of stock employed at the time of compilation of the list. Unless otherwise noted, and except for Electronic Measurements Company (EMC) numbers, "or equal" parts may be used for replacement. Electronic Measurements Company reserves the right to replace a part with an "or equal" part. When ordering parts from Electronic Measurements Company, include the model and serial numbers of the instrument. Note carefully and include the letter suffix of any transformer number. In case of a discrepancy between a parts list number and the number actually printed on the part, employ the latter.

5-2. DIAGRAMS. The following illustrations and diagrams are included in this section for reference during installation and maintenance work.

a. Parts location illustrations, figures 5-1 through 5-3.

b. Outline drawing, figure 5-4, for Models PVC36-30 and PVC60-15.

c. Schematic diagram, figure 5-5.

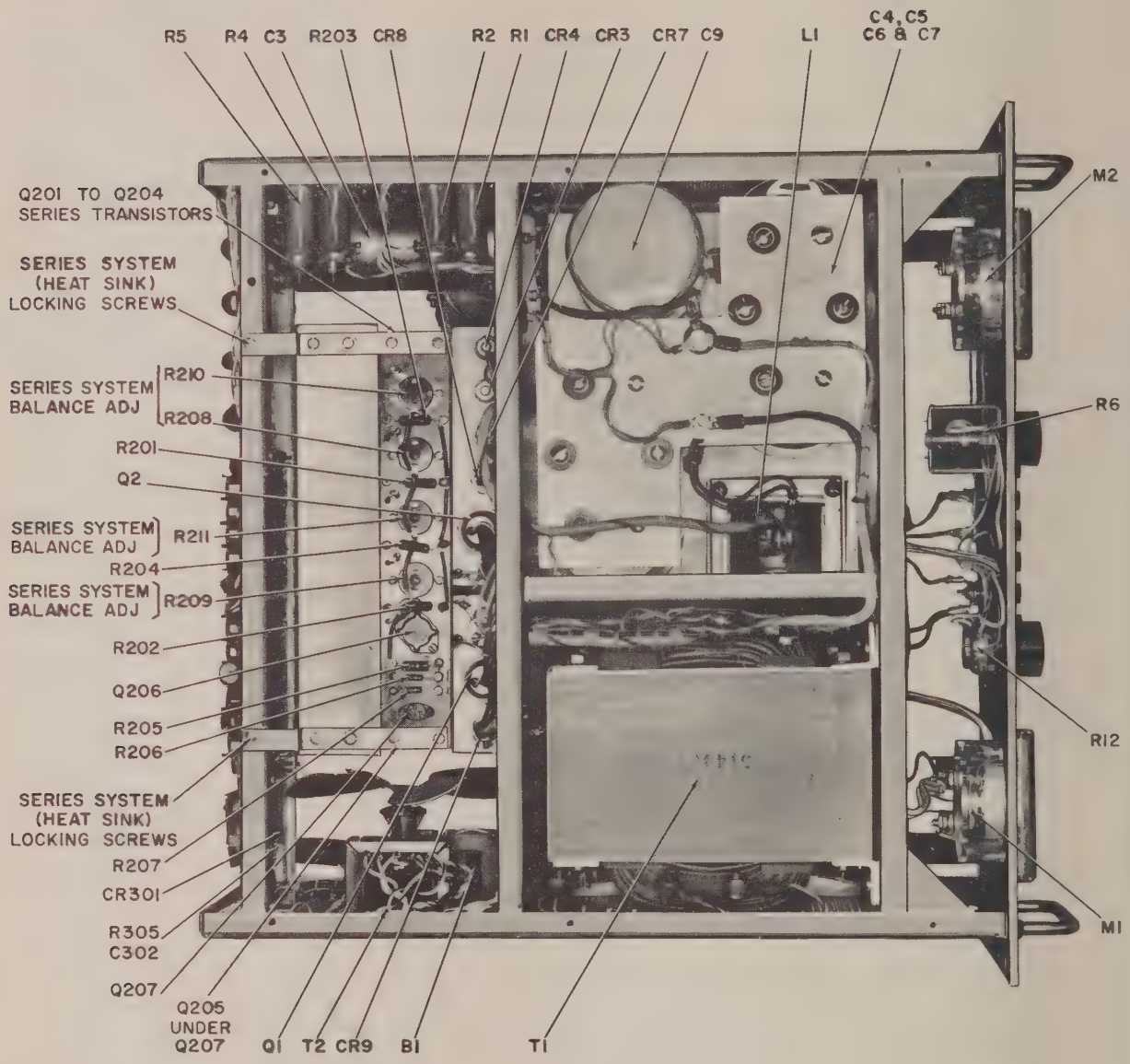


Figure 5-1. Parts location, top view.

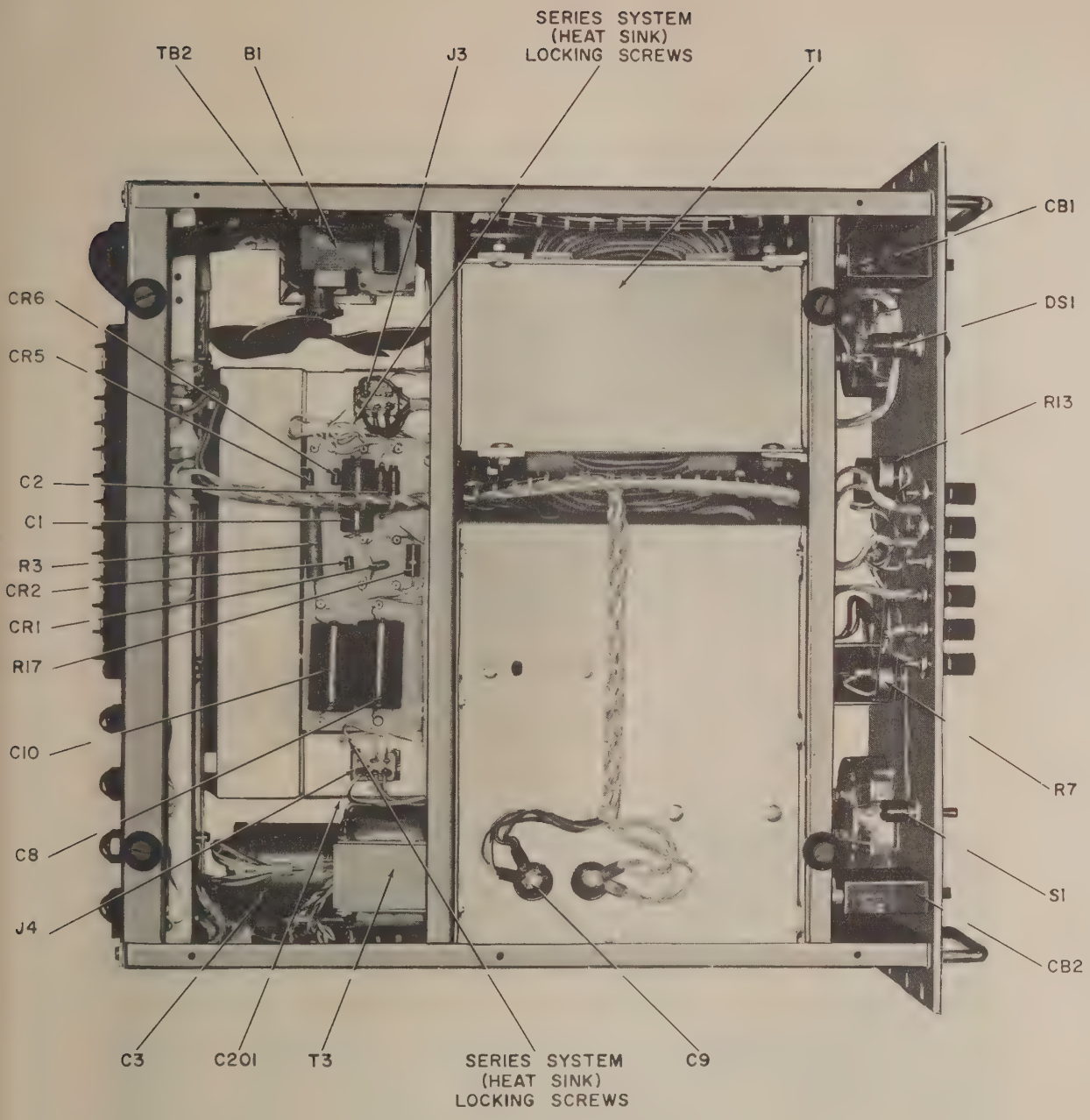


Figure 5-2. Parts location, bottom view.

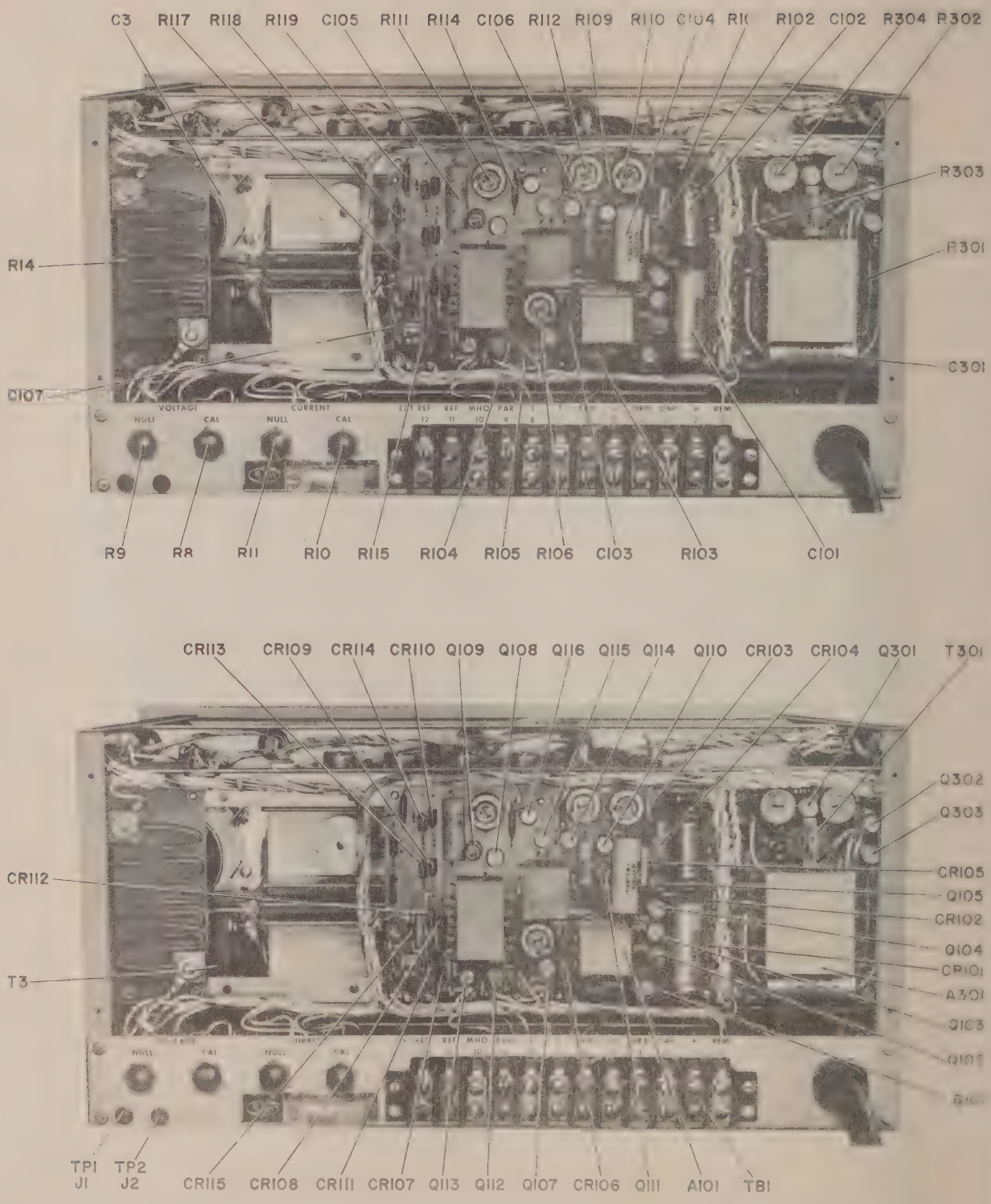


Figure 5-3. Parts location, rear view.

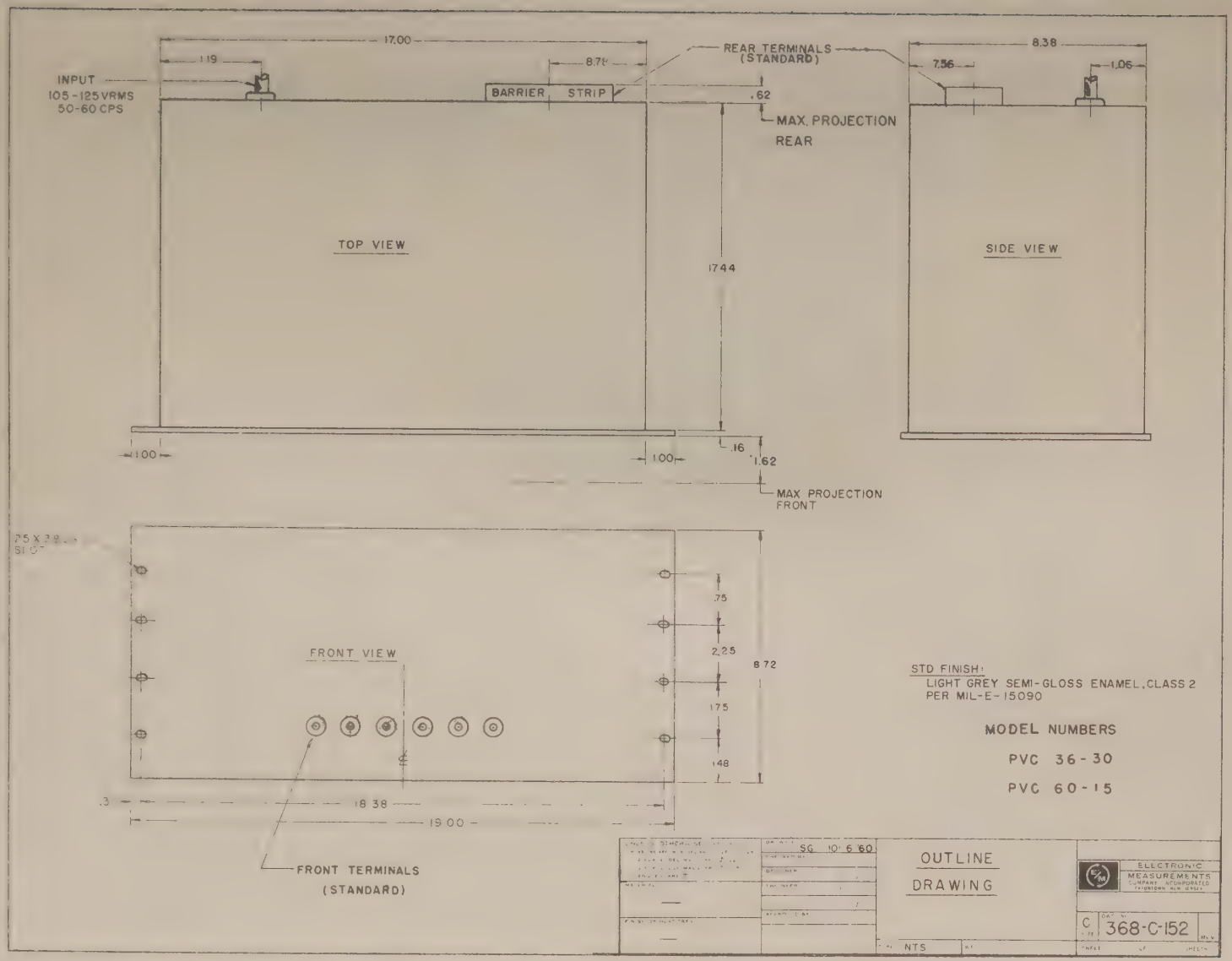


Figure 5-4. Outline drawing, models PVC36-30 and PVC60-15.

ELECTRONIC MEASUREMENTS, A DIVISION
OF THE ROWAN CONTROLLER COMPANY

CHANGES TO PARTS LIST

MODELS PVC 36-30 AND PVC 60-15

Make the following changes in reference designations:

Change R301 to R302

R305 to R316

R304 to R312

R302 to R309

R303 to R308

C302 to C304

CR301 to CR306

ELECTRONIC MEASUREMENTS COMPANY
EATONTOWN, NEW JERSEY

8/63

PARTS LIST

MODELS PVC36-30 AND PVC60-15

PROGRAMMING CONSTANT
1000 ohms-per-volt
115 volts, 50-60 cps input

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
B1	Motor, shaded pole, 115V, 50-60 cps, 5-1/2-in. fan blade	1175	Howard Industries
*C1	Capacitor, electrolytic, 500 uf, 25 vdc	500/25	Frako
*C2, C2A	Capacitor, electrolytic, 25 uf, 25 vdc (PVC36-30 only)	25, 25/30	Neuberger
*C2, C2A	Capacitor, electrolytic, 25 uf, 30 vdc (PVC60-15 only)	25/30	Neuberger
*C3	Capacitor, electrolytic, 20,500 uf, 10 vdc	D37613	Sprague
*C4, C5, C6, C7, C9	Capacitor, electrolytic, 20,000 uf, 50 vdc	20-72242	Mallory
*C8, C10	Capacitor, electrolytic, 200 uf, 100 vdc (PVC36-30 only)	200/100	Frako
*C8, C10	Capacitor, electrolytic, 100 uf, 200 vdc (PVC60-15 only)	100/200	Frako
*C101	Capacitor, electrolytic, 250 uf, 50 vdc	20-41131	Mallory
*C102	Capacitor, electrolytic, 500 uf, 15 vdc	EN540-500-15	Neuberger
C103	Capacitor, fixed, mica, 0.005 uf, 500 vdc	CM208-502-J	Micamold
C104	Capacitor, fixed, paper, 1 uf, 150 vdc (PVC36-30 only)	107V105K	General Instrument
C104	Capacitor, fixed, paper, 0.5 uf, 200 vdc (PVC60-15 only)		General Instrument
C105	Capacitor, fixed, paper, 0.5 uf, 200 vdc	2589X	Chicago Condenser
C106	Capacitor, fixed, Mylar, 0.1 uf, 200 vdc	107C104K	General Instrument
*C107	Capacitor, fixed, antalum, 4.7 uf, 100 vdc	109D-7X01002	Sprague
C201	Capacitor, fixed, mica, 0.005 uf, 500 vdc (PVC36-30 only)	CM20B-502-J	Micamold
C201	Capacitor, fixed, mica, 2200 uf, 300 vdc (PVC60-15 only)		
*C301	Capacitor, electrolytic, 250 uf, 50 vdc	20-41131	Mallory
C302	Capacitor, fixed, Mylar, 0.1 uf, 200 vdc (PVC36-30 only)	107C104K	General Instrument
CB1	Circuit breaker, 33 amp	PAM 12	Heinemann
CB2	Circuit breaker, 38 amp (PVC36-30 only)	PAM 12	Heinemann
CB2	Circuit breaker, 20 amp (PVC60-15 only)	PAM 12	Heinemann
*CR1, CR2, CR5, CR6	Diode, silicon	HC-69	Solitron
*CR3, CR4	Diode, silicon	1N3210	Motorola
*CR7	Diode, silicon	1N1186	RCA
*CR8, CR9	Diode, silicon (PVC36-30 only)	1N1186	RCA
*CR101, CR102, CR107, CR108, CR109, CR110, CR111, CR112, CR113, CR114, CR115	Diode, silicon	HC-69	Solitron
*CR103, CR106	Diode, silicon, Zener	1N706	Hughes
*CR104, CR105	Diode, silicon, Zener	1N823	Motorola
*CR116	Diode, silicon, Zener (PVC60-15 only)	1/4M68Z5	Motorola
*CR301	Diode, silicon, Zener	1N768	Hughes
DS1	Glow lamp	NE-51	GE
E1, E2, E3	Binding post assembly, 5-way, red	29-3	Grayhill
E4, E5, E6	Binding post assembly, 5-way, black	29-3	Grayhill
J1, J2	Tip jack, nylon, black	105-603	E.F. Johnson
J3, J4	Socket, connector	S-306-AB	Cinch
L1	Choke (PVC36-30 only)	5169C	EMC
L1	Choke (PVC60-15 only)	5224	EMC
M1	Ammeter 0-36 amp (PVC36-30 only)	346-C-61-43	EMC
M1	Ammeter 0-18 amp (PVC60-15 only)	346-C-61-42	EMC
M2	Voltmeter, 0-36 v (PVC36-30 only)	346-C-61-5	EMC
M2	Voltmeter, 0-60 v (PVC60-15 only)	346-C-61-7	EMC
P1	Line cord assembly	346-B-193-3	EMC
P203, P204	Plug, connector	P-306-AB	Cinch
*Q1, Q2	Silicon-controlled rectifier (PVC36-30 only)	2N1910	GE
*Q1, Q2	Silicon-controlled rectifier (PVC60-15 only)	2N683	GE
*Q101, Q104, Q105	Transistor, silicon, NPN	2N1700	RCA
*Q102, Q116	Transistor, silicon, NPN	2N696	RCA
*Q103, Q108, Q109, Q110, Q111, Q112, Q113, Q114, Q115	Transistor, silicon, PNP	EM206	EMC
*Q107	Transistor, silicon, NPN (PVC36-30 only)	2N1700 or RD-60	RCA or Radco
*Q107	Transistor, silicon, NPN (PVC60-15 only)	2N657 or RD-60	STC or Radco
*Q201, Q202, Q203, Q204	Transistor, silicon, NPN (PVC36-30 only)	EM201	EMC
*Q201, Q202, Q203, Q204	Transistor, silicon, NPN (PVC60-15 only)	EM202	EMC
*Q205	Transistor, silicon, NPN (PVC36-30 only)	EM203	EMC
*Q205	Transistor, silicon, NPN (PVC60-15 only)	EM202	EMC
*Q206	Transistor, silicon, NPN (PVC36-30 only)	2N1701	RCA
*Q206, Q207	Transistor, silicon, NPN (PVC60-15 only)	2N657	STC
*Q207	Transistor, silicon, NPN (PVC36-30 only)	2N1700	RCA
*Q301, Q302	Transistor, silicon, NPN	2N696	RCA
*Q303	Transistor, silicon, PNP	EM206	EMC
R1, R2	Resistor, fixed, ww, 400 ohms ±5%, 25w (PVC36-30 only)	25F400	Ward Leonard
R1, R2	Resistor, fixed, ww, 2K ±5%, 25w (PVC60-15 only)	T2000L	Ward Leonard
R3	Resistor, fixed, ww, 2 ohms ±5%, 10w	10X2WL	Ward Leonard
R4, R5	Resistor, fixed, ww, 400 ohms ±5%, 25w (PVC36-30 only)	25F400	Ward Leonard
R4, R5	Resistor, fixed, ww, 800 ohms ±5%, 25w (PVC60-15 only)	25F800	Ward Leonard
*R6	Resistor, variable, ww, 36K (PVC36-30 only)	972-S-12	General Radio
*R6	Resistor, variable, ww, 60K (PVC60-15 only)	972-S-13	General Radio
*R7	Resistor, variable, ww, 1K, 1/2-in. lg shaft	Series 43	Clarostat
*R8, R10	Resistor, variable, ww, 500 ohms, 1/8-in. lg slotted shaft	Series 43	Clarostat
*R9	Resistor, variable, ww, 100 ohms, 1/8-in. lg slotted shaft	Series 43	Clarostat
*R11	Resistor, variable, ww, 10 ohms, 1/8-in. lg slotted shaft	Series 43	Clarostat
*R12	Resistor, variable, ww, 100 ohms, 1/2-in. lg shaft	Series 43	Clarostat
*R13	Resistor, variable, ww, 20 ohms, 1/2-in. lg shaft	Series 43	Clarostat
R14	Resistor, fixed, ww, 0.033 ohms, 60w (PVC36-30 only)	369-B-32-6	EMC
R14	Resistor, fixed, ww, 0.066 ohms, 30w (PVC60-15 only)	369-B-32-5	EMC

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
R15, R16	Resistor, fixed, ww, 800 ohms ±5%, 25w (PVC60-15 only)	25F800	Ward Leonard
R17	Resistor, fixed, comp., 270 ohms ±5%, 1w	GB	Allen-Bradley
R101	Resistor, fixed, comp., 150 ohms ±10%, 1w	GB	Allen-Bradley
R102, R103, R109	Resistor, fixed, comp., 560 ohms ±10%, 1/2w	EB	Allen-Bradley
R104	Resistor, fixed, comp., 470 ohms ±10%, 1/2w	EB	Allen-Bradley
R105	Resistor, fixed, comp., 6.8K ±10%, 1/2w	EB	Allen-Bradley
*R106, R111, R112	Resistor, variable, ww, 5K (3-prong PC type)	Series 39	Clarostat
*R110	Resistor, variable, ww, 300 ohms (3-prong PC type)	Series 39	Clarostat
*R114, R119	Resistor, fixed, ww, 500 ohms ±1%, 1/3w	TX-156	Precision Resistor
R115	Resistor, fixed, comp., 47 ohms ±10%, 1/2w	EB	Allen-Bradley
*R117	Resistor, fixed, ww, 5K ±1%, 3w	RS-2B	Dale Electronics
*R118	Resistor, fixed, ww, 1K ±1%, 1/3w	TX-156	Precision Resistor
R120	Resistor, fixed, comp., 1K ±10%, 1/2w (PVC60-15 only)	EB	Allen-Bradley
R201, R202, R203, R204	Resistor, fixed, ww, 0.05 ohms ±5%, 3w (PVC36-30 only)	CS-2-3W	Dale Electronics
R201, R202, R203, R204	Resistor, fixed, ww, 0.1 ohms ±5%, 3w	CS-2-3W	Dale Electronics
R205	Resistor, fixed, comp., 470 ohms ±10%, 1w	GB	Allen-Bradley
R206	Resistor, fixed, comp., 1K ±10%, 1/2w	EB	Allen-Bradley
R207	Resistor, fixed, comp., 10K ±10%, 1/2w	EB	Allen-Bradley
*R208, R209, R210, R211	Resistor, variable, ww, 2 ohms	WC808A	Chicago Condenser
*R301	Resistor, fixed, ww, 172 ohms ±1%, 5w	RS-5-5W	Dale Electronics
*R302	Resistor, variable, ww, 5K (3-prong PC type)	Series 39	Clarostat
R303	Resistor, fixed, comp., 5.1K ±5%, 1/2w (PVC36-30 only)	EB	Allen-Bradley
R303	Resistor, fixed, comp., 18K ±10%, 1/2w (PVC60-15 only)	EB	Allen-Bradley
*R304	Resistor, variable, ww, 5K (4-prong PC type)	Series 39	Clarostat
R305	Resistor, fixed, comp., 39K ±10%, 1/2w	EB	Allen-Bradley
*S1	Switch, toggle, SPST	160-73	Carling Electric
T1	Transformer, power (PVC36-30 only)	5144-1G	EMC
T1	Transformer, power (PVC60-15 only)	5148A	EMC
T2	Transformer, reference	5258C	EMC
T3	Transformer, booster	5240	EMC
T301	Transformer, pulse	5140E	EMC
TB1	Barrier strip, 12 term.	12-142-Y	Cinch
TB2	Barrier strip, 2 term.	2-140-W	Cinch
XDS1	Pilot lamp holder, colorless plastic dome	101N	Drake

NOTES:

1. *Asterisked parts are recommended spares in quantity of one per reference symbol, except fuses, which are three per reference symbol. When electrolytic capacitors are to be stored as spares for a year or more, request Technical Note 32.

2. Part numbers are indicative of stock employed at the time of compilation of this list. Unless otherwise noted, and except for Electronic Measurements Co. (EMC) numbers, "or equal" parts may be used for replacement. Electronic Measurements Co. reserves the right to replace a part with an "or equal" part.

3. When ordering parts from Electronic Measurements Co., include model and serial numbers of the instrument. Note carefully and include the letter suffix of any transformer number. In case of a discrepancy between a parts list number and the number actually printed on the part, employ the latter.

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